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Knowledge Building/Knowledge Creation in the School, Classroom and Beyond

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Introduction

Knowledge creation and innovation are now becoming increasingly pervasive and essential in our changing world; globalization, exponential growth in technology, and knowledge economies have brought unprecedented changes, highlighting the need for lifelong learning, innovation, and new competencies to solve problems of the future. These changes have created new demands for educational goals and new pedagogical models of education. Although technological change is ubiquitous, and knowledge explosion has transformed all aspects of society, educational paradigms and models have been slow in responding to changing societal needs. There is a need to shift from the instructivism prevalent in schooling to deep understanding and creative knowledge work (Sawyer, 2014). While there are many challenges, technological advances have made it possible to develop collaborative and innovative communities for improved classroom and school systems and continual advances in Knowledge Building processes and practice (Fischer, Hmelo-Silver, Goldman, & Reimann, 2018; Hmelo-Silver. Chinn, Chan & O'Donnell, 2013).

Knowledge Building is a major research theme of computer-supported collaborative learning (CSCL) and learning sciences (Yoon & Hmelo-Silver, 2017). Knowledge Building is synonymous with knowledge creation as studied in organizational science, but with an added concern for educational benefit to the participants (Bereiter & Scardamalia, 2014). Supported by Knowledge Forum® (KF), Knowledge Building represents the kind of productive knowledge work found in scientific and research communities (Bereiter, 2002; Scardamalia & Bereiter, 2006). Thus, it is characterized by design thinking as the primary mode of interacting both with academic subject matter and with tools and materials in more hands-on educational activities. Also in keeping with its knowledge-creating character, Knowledge Building focuses on the construction of knowledge as a social product of value to the community rather than focusing exclusively on individual knowledge and skill. Scardamalia and Bereiter (2014) discussed the distinction between Knowledge Building, which has been used widely to denote variants of joint construction of understanding and their postulation of Knowledge Building focusing on the creation and production of new knowledge. They argued for an education agenda that helps students see their work as part of a civilization-wide effort to advance the knowledge frontier of the community.

Knowledge Building thus constitutes a direct approach to education for a knowledge society, by engaging students in the actual work of a knowledge society, in contrast to many other less direct approaches that emphasize engaging students in activities believed to develop competencies believed to be relevant so work in a knowledge society. In Knowledge Building such competencies are a natural outgrowth of creative knowledge work. Knowledge Building takes seriously Peter Drucker's pronouncement (1985, p.151) that in order for innovation to take hold and flourish, "innovation must be part and parcel of the ordinary, the norm, if not routine." Teachers work to transform classrooms into Knowledge Building communities, helping students to take over knowledge processes traditionally carried out by the teacher, such as problem formulation, analysis, and reformulation; evaluating collective progress; recognizing and dealing with obstacles; recognizing promising ideas and taking responsibility for idea improvement.

While education documents/ICT frameworks (e.g., UNESCO ICT framework for teachers, pp.13-15) now advocate knowledge creation, how the Knowledge Building model aligns with current approaches, practices, and policies for theory-practice synergistic advances needs to be examined. This discussion paper outlines the background of and need to examine Knowledge Building/creation, then examines the nature of Knowledge Building, emphasizing theory, pedagogy, and technology integration. Following that, it examines principle-based Knowledge Building pedagogy and designs in the classroom, teacher professional development in professional communities, and how Knowledge Building can be sustained and scaled up with enabling conditions.

The goal of this working group is to examine how Knowledge Building might be aligned with future-looking local and regional educational policies and pedagogical and assessment tools. Challenges for the workgroup include building on the established research to identify exemplars and determining what is required for better alignments and theory-design-policy synergistic advances.

Why is Knowledge Building/Knowledge Creation important? What kinds of key competencies for 21st-century education are developed?

Globalization and knowledge economies, along with the rapid development of technology, are continually transforming the ways in which people live, work, and learn. Innovation is central to resolving complex and wicked problems whose solutions are as yet unknown. Over the past few centuries at an ever-accelerating pace, the human race has generated ideas and technologies that have transformed human existence for the better (Pinker, 2018). However, in the 21st century the unintended and unforeseen consequences of those ideas and technologies have brought humanity to the brink of at least two catastrophic events—nuclear Armageddon and climate change—of comparable significance to the asteroid that exterminated the dinosaurs. We find ourselves in a bewildering and increasingly complex world shaped by the transformative impact of digital technologies and networks, in which computer algorithms shape human perceptions and beliefs. The early childhood to post-secondary education system is the one social institution specifically tasked with preparing young people not only to survive and thrive in this complexity but to shape it productively.

Facing these challenges and global change, new educational goals emerge regarding developing creative knowledge work and 21st century education skills, as can be seen in the educational policies and initiatives of different countries. For example, Canadian policy makers, researchers, and practitioners have been sensitive to the importance of developing collaborative competencies, and have fostered computer-supported collaboration through a number of initiatives, researches, and intervention programs (e.g., TeleLearning Network of Centres of Excellence, 1995-2002; Beyond Best Practices (2002-2007, Galileo Educational Network, 1999-2019). The Council of Ministers of Education recently published a national analysis of the PISA results (CMEC, 2019; OECD, 2017) and such educational efforts have likely helped the fifteen-year-old students show above average results. CMEC coordinated the Canadian delegation at the 2018 OECD Skills Summit in Portugal, where they explored the theme "Skills for a digital world"; "The summit provided a platform to highlight Canada's commitment to promoting deeper learning and to ensuring measurable benefits for multiple areas of life, for all students and society as a whole" (report, p. 6).

The democratization of knowledge, a key Knowledge Building principle, is both a vision shared by Knowledge Building researchers and a skill developed in Knowledge Building communities. It resonates with workplace leaders' calls for preparing school graduates to be capable of sharing their knowledge for successful integration in their organizations. Those having some experience with the co-creation of knowledge (UNESCO, 2011) are likely to thrive, as ever more organizations engage further in the affordances of the digital age.

In New Zealand, schools and teachers, both primary and secondary, use the recent New Zealand Curriculum (2007) to develop their courses and learning units, highlighting five key competencies: thinking; using language, symbols, and texts; managing self; relating to others; and participating and contributing. Knowledge Building/creation is central to all these competencies. Educators and policymakers in New Zealand emphasize future-oriented teaching and learning focusing on innovation and creativity, which are key domains related to Knowledge Building/knowledge creation. In Singapore, policymakers, researchers, and practitioners have set important educational goals related to developing students' knowledge creation capacity through Knowledge Building—engaging students in deep constructivist learning, developing students' 21st-century skills, and developing students' capacity for contributing to the cultural efforts of progressive disciplines.

Knowledge Building, is well-aligned with educational documents and policies for preparing new kinds of learners and learning processes for the knowledge era and digital age -- the effort of developing students' knowledge creation capacity contributes to the knowledge economy, where new ideas and innovative products, rather than conventional manufacturing industries, are driving the economic growth (Castells, 2010). There is a clarion call for preparing students for new challenges in the 21st Century (Partnership for 21st Century Skills, 2008), and corresponding advocacy on developing knowledge innovation capacity and digital literacy of students, for the pragmatic goal of contributing to the new economies (Anderson, 2008). Beyond economic values, these new capabilities and competencies are essential for students' social well-being as they become citizens of modern societies.

Any contributing citizens will need to fulfill their obligations and expectations in a social environment, including economic contribution, so that they can develop social ties within a community and across communities (Zinnbauer, 2007).

Knowledge Building is compatible with many learning sciences and constructivist approaches that emphasize on problem solving, inquiry, discourse and use of technology (Fischer et al., 2018). Constructivist learning and inquiry-based approaches, generally, recognize the importance of students constructing their own understanding rather than receiving or mirroring the knowledge structure of objective truth out in the world. While new pedagogy and technology are advocated in schools, superficial design of constructivist learning often leads to "busy work" or "chattering" in classrooms, which may mask key educational goals. Knowledge Building/creation aims to engage students in deep constructivist learning by engaging them directly in working with their ideas through collaborative and progressive discourse supported by technology (Scardamalia, 2002). Several related student dispositions are developed in tandem through this knowledge-creation effort, and including collective cognitive responsibility and epistemic agency, students taking responsibility and agency for continual collective idea improvement.

From a broader perspective, the impact of Knowledge Building/creation model goes beyond economic contribution, socialization and cognitive growth. It is developing students' capacity to contribute to any progressive knowledge-based enterprise, be it a learned discipline, a profession, a business, or a problem-oriented task force. Any progressive disciplines enterprise advances the knowledge in the field collectively through community effort: there is building-on of one another's ideas, peer-reviewing of creative work, upholding of the epistemic criteria sanctioned by the community, communication, and sharing of new discoveries, and so on. The cultural practices of Knowledge Building in classrooms are fundamentally the same as the cultural practices in any progressive field (Scardamalia & Bereiter, 2014). Knowledge Building is thus a way to transform education in a radical way by initiating students into a knowledge-creating culture. In KB students work in digital-rich Knowledge Building environments and they engage in dialogue similar to that found in knowledge disciplines and innovative communities (Paavola, Lipponen, & Hakkarainen, 2004). Supported by design and technology, school-aged students can work in similar ways as scientists and innovators, pushing the frontiers of knowledge of their community through progressive discourse (see review for evidence, Chen & Hong, 2016; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007; 2018).

There has been much emphasis on 21st-century education competencies (Trilling & Fadel, 2009) using different frameworks and interpretations. ICT education is also called to action to explore ways to develop such competencies, and there have been efforts to examine 21st-century competencies in relation to new models of assessment and continua that move from school-based skills to actual characteristics of knowledge-creating organizations (Appendix 1). Knowledge Building maps directly on to knowledge-creating organization characteristics and may provide a unifying lens emphasizing collective progress for 21st-century competencies, and the developmental perspectives may provide some standards for evaluating different educational environments (https://cutt.ly/Iw7WDSj). Examples of different technology-enhanced environments including Knowledge Building examples from

different countries may be examined to explore the question of fostering 21st century competencies for knowledge creation.

What is the theoretical background and what are the characteristics of the Knowledge Building/creation approach?

The Knowledge Building/creation model originated in cognitive research on writing processes in the 1980s, which distinguished between 'knowledge telling', in which students retell what they know in writing, and 'knowledge transformation', in which students restructure their knowledge during writing) (Bereiter & Scardamalia, 1987a). In the 1980s and 1990s, research on intentional learning examined differences between learning as task completion versus learning as an explicit goal and found expert learners employ constructive learning efforts over and above task completion; expertise involves reinvesting cognitive efforts to understanding problems at progressively deeper levels (Bereiter & Scardamalia, 1993). These research results show how students can take high-level agency brought about further development. Scardamalia & Bereiter developed a prototype computer-supported intentional learning environment (CSILE) in 1986, followed by Knowledge Forum (KF) launched in 1997, with continuing development to date, to make advanced knowledge-creation processes accessible to school-aged children. Theory, pedagogy, and technology are integral to each other; Knowledge Forum and technology affordances illuminate and support knowledge-creation processes, and design-based classroom studies contribute to evolving theory and design. The key characteristics of Knowledge Building/creation model and relevance for addressing contemporary education goals are discussed as follows

<u>Epistemic Aims</u>

Learning and Knowledge Building. A first distinction is made between learning and Knowledge Building, with the former focusing on individual growth and the latter on public ideas and theories (Scardamalia & Bereiter, 2006). A main goal of learning is for students to acquire knowledge of their intellectual heritage, and in Knowledge Building, the goal is to advance the state of community knowledge while learning also takes place. Knowledge Building in schools is the educational variant of knowledge creation: the process by which new knowledge is created in science, engineering, medicine, and other fields of human endeavor. Knowledge creation, as an educational goal, is "a civilization-wide human effort to extend the frontiers of knowledge" (Scardamalia and Bereiter, 2006). As such, knowledge creation is not just for experts; if knowledge-creation is now a major educational goal, then students also need to learn the processes by which knowledge is created.

Belief mode and design mode. Another distinction is made between design mode and belief mode. 'Design-mode thinking' emphasizes that Knowledge Building, like design, is an open-ended journey (Scardamalia & Bereiter, 2006), much as when a cell phone manufacturer produces the prototype of a certain design, but almost immediately begins the design work necessary for the next version thereof. Similarly, idea improvement is a continual process of inquiry in which knowledge begets knowledge. In contrast, belief-mode thinking, which involves reasoning, evidence, and evaluation of claims, is more prevalent in schools and is generally less open-ended than design-mode thinking. In belief mode, the discourse often stops when some arguments prevail; debate is a format that perpetuates belief-mode thinking.

Knowledge Building requires a discourse that develops new ideas, and therefore needs to focus on how these can be developed, tested, and improved; design-mode thinking involves an ever-deepening process of explanation and theory-building.

Knowledge Building Principles

Another key theme of the Knowledge Building/creation model involves a set of twelve Knowledge Building principles. KB principles help illuminate the model and provide guidelines for researchers and teachers for designing knowledge work. These principles represent the goals and dynamics of Knowledge Building, for example, idea improvement, epistemic agency, community knowledge, democratization of knowledge, the power of idea diversity, the reflective and agenda-setting role of embedded and transformative assessment (for details, see Scardamalia, 2002). KB principles focus on the epistemic notions that ideas are improvable objects — students take agency grappling with diverse models, using contrasts to spark progress, with all of these directed at advancing the state of knowledge in the community. Appendix 2 shows the socio-cognitive and socio-technological dynamics of the KB principles (Scardamalia, 2002).

CSCL and learning sciences models have often focused on developing conceptual/domain knowledge, and designing inquiry tasks and problems to help students learn through problem solving (Fischer et al., 2018). Knowledge Building places less emphasis on pre-defined goals, but instead starts from the question of how far a community can advance from where it starts. An important goal is understanding how knowledge is created and the social nature of this process. Today's world provides exciting opportunities for Knowledge Building by young people and requires a radically different model for how young people go about becoming knowledgeable, confident, and capable citizens of the world.

Knowledge Building, apart from enabling young people to develop important knowledge, has some important meta-knowledge purposes and effects. Some of these have to with understanding themselves as people who can build knowledge (e.g., metacognition, self-regulation, shared regulation); others have to do with students reflecting on what is involved in productive discourse as ways to build knowledge; and to evaluate the value of knowledge work such as considering idea improvement and impact, not just learning outcomes. Knowledge Building principles may constitute a form of entry point into meta-knowledge that students can use to work with knowledge, enriching new kinds of 21st century competencies. How teachers and students come to understand these principles (and creating new ones), and how these principles can be examined as meta-knowledge to enrich theory and design continue to be important questions.

What are the technologies of Knowledge Building and how do they support students' creative work with ideas?

Features of Knowledge Forum

Knowledge Building entails transforming traditional relations between the teacher, students, and ideas in the classroom (Zhang, Scardamalia, Reeve, & Messina, 2009; Teo, 2014): Student ideas are at the center of all activities, and everyone works together to improve those ideas (Scardamalia, 2002). Central to the Knowledge Building model is Knowledge Forum, a computer-based online environment

optimized for making ideas public and enabling students to work together to advance community knowledge (Scardamalia & Bereiter, 1991; 1994; Scardamalia, 2004). When students work to investigate problems of understanding, they enter their explanations and research findings into the Knowledge Forum database. Some key features of Knowledge Forum include:

- Shared collaborative workspace, called 'views', provide a place for students' ideas to be made public to the rest of the community. Students can read through the knowledge base and make their own contributions; views have graphical interface and different ideas can be grouped and improved collectively (Figure 1, top).
- Student contributions can take many forms, including: 'Notes', in which students state problems, advance initial theories, summarize what needs to be understood to progress on a problem or improve their theories, provide a drawing or diagram, etc. The note build-on structure is different from the threaded discourse for flexible work with ideas. When writing note, they can use scaffolds (e.g., I need to understand, my theory, a better theory) and tag keywords, to support idea improvement, (Figure 1, bottom left) notes are linked in multiple ways and they can be moved to different views.
- Rise Above processes include 'rise-above views' and 'rise-above notes' that synthesize other notes in the knowledge base; and 'reference note's include hyper-links to other ideas, similar to scientists citing other ideas in the community.
- Embedded, concurrent assessment via analytic tools. Accompanying KF is a set of assessment and learning analytics tools that record students' online activities and dialogues such as note contributions, interactivity (social network analysis), use of scaffolds and lexical analysis for vocabulary growth (see Figure 1, bottom right). Students can monitor their work and engage in self/collective assessment of their progress using these tools

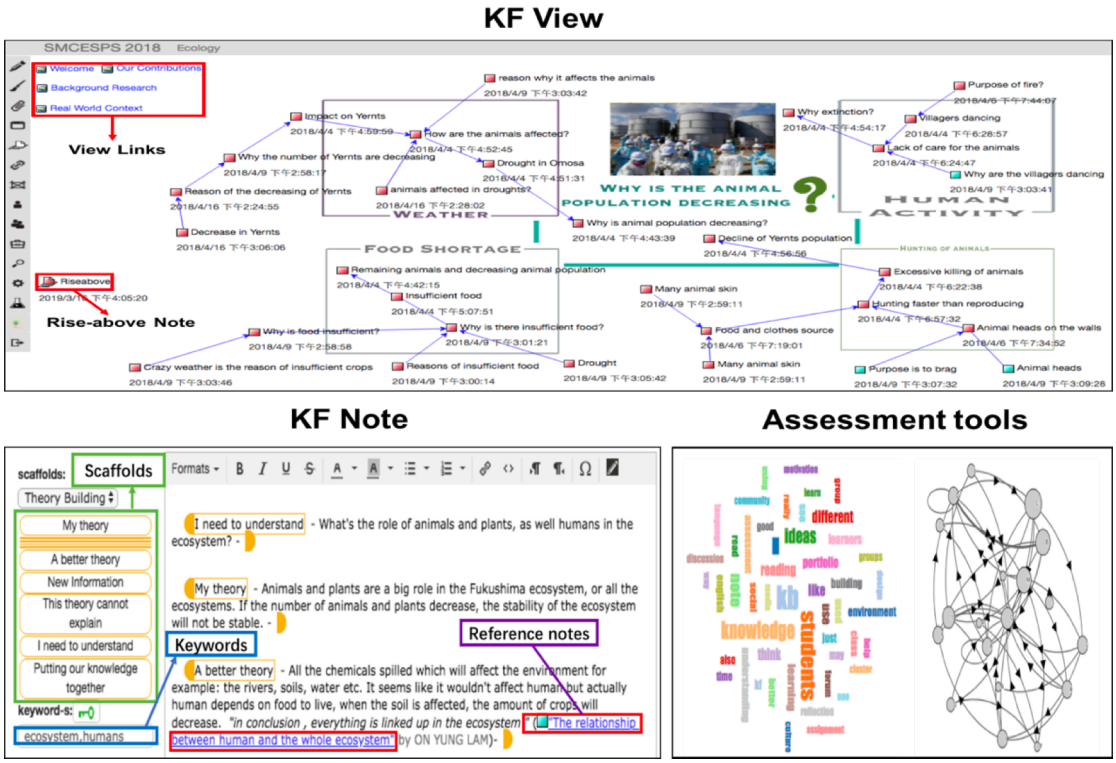

Figure 1: Features of Knowledge Forum: (a) top - 'View'- collaborative workspace for collective idea development; (b) Bottom left: 'Note' including scaffolds, keywords, and (c) references; Bottom right: KF6 assessment tools.

Current KB technology (KF6 version) involves major developments in analytics and assessments, aligned with current trends in CSCL and learning sciences. For example, with the Idea Thread Mapper (ITM) https://idea-thread.net/, students can identify related notes on a specific problem and create idea-threads to trace idea development, document their journey of thinking, and identify new problems (Zhang et al., 2018). Knowledge creation is based on pursuing promising ideas -- a 'promising idea' tool has been developed that supports young students evaluating promising ideas in their community; these ideas are aggregated and visualized to support students moving toward deeper inquiry (Chen, Scardamalia & Bereiter, 2015) (Figure 2.) The Knowledge Building Discourse Explorer http://www.kbdex.net/ (Oshima et al, 2012), traces the connections among ideas in KF writing (similar to SNA) and examines students' collective responsibility (Figure 2.). Technology development is intertwined with research-based design studies in classrooms (e.g., Zhang et al., 2018)

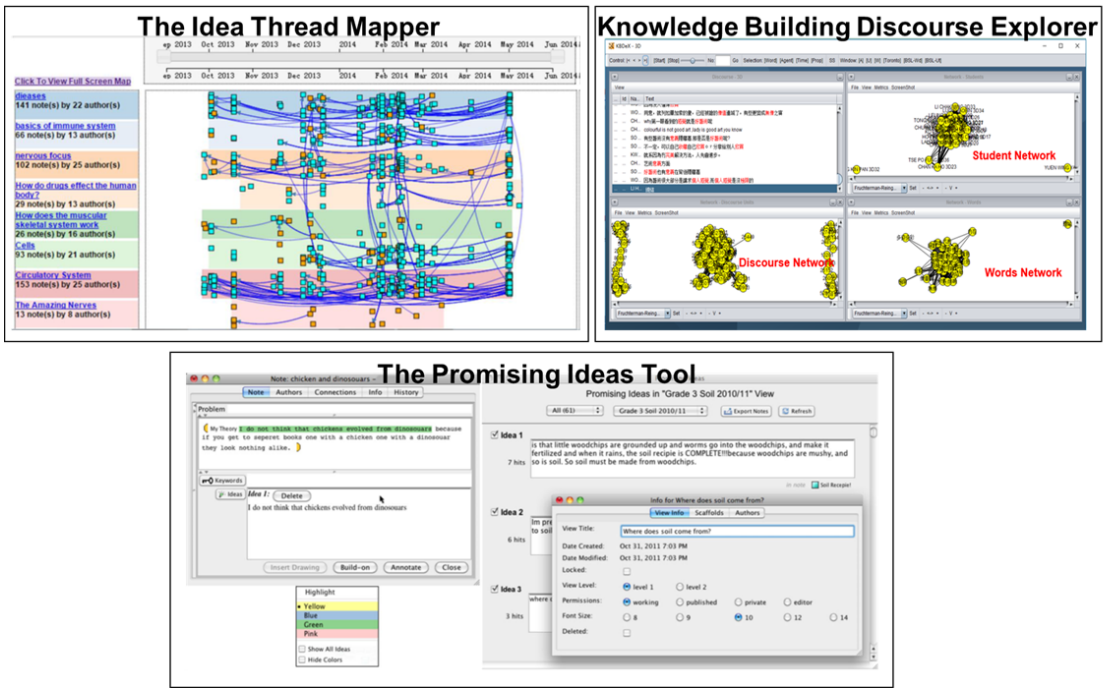

Figure 2. Knowledge Building idea development and assessment tools. Top left: The Idea Thread Mapper; Top right: Knowledge Building Discourse Explorer; Bottom: The Promising Ideas Tool

How Knowledge Forum Supports Creative Knowledge Work

Digital spaces, such as Knowledge Forum (Scardamalia & Bereiter, 2014), help make Knowledge Building pervasive by breaking down barriers between the ideas that live inside and outside the classroom. The process of Knowledge Building is a form of progressive inquiry (Hakkarainen, 2004) that continuously self-generates new and unexpected cycles of knowledge advancement. Hence, productive discourse moves on KF go beyond simply asking questions and finding answers to problems; it involves problem redefinition, seeking out diverse ideas, judging promising ideas, and reflective metadiscourse (Bereiter & Scardamalia, 2016).

Using Knowledge Forum, students can contribute questions, ideas, and theories and visualize their ideas evolve over time. They can write notes, create drawings, upload videos featuring authentic problems from their daily lives, critique authoritative sources from the Internet, and build on different ideas in the community. The embedded assessment/analytics tools in Knowledge Forum (Figure 2) play a critical role for sustaining and deepening creative work with ideas. These tools make the Knowledge Building process more transparent by helping students visualize their contribution patterns (Chen et al., 2015) and interaction dynamics (Philip, 2010) so that they may self-organize in more productive ways. Similarly, students can also visualize their community knowledge as idea clouds (Resendes, Scardamalia, Bereiter, Chen, & Halewood ,2015), idea threads (Zhang et al., 2018), and idea networks (Oshima et al., 2012) to identify areas that need further work. Ongoing work in classrooms shows that students as young as 7 and 8 years of age have an intuitive understanding of the use and limitations of our analytic tools.

Importantly, Knowledge Forum allows learners to construct a communal multimedia knowledge base where student-constructed knowledge "artifacts" not only become available for progressive improvement by community members but also make visible the knowledge and inquiry processes engaged in by students. This visibility and accessibility permits students to reflect on the community discourse and have meta-level discussions about both the knowledge they build and how they build it (termed "meta-discourse"). As an online knowledge base, Knowledge Forum affords wider access, greater manipulation capabilities, searchability, and visualization than inquiry using only oral discussions or physical spaces for sharing work. Further, Knowledge Forum permits the work of a single classroom to be extended, "via the Internet, to a broader community of knowledge workers". Research is currently underway examining the impacts of extending work beyond a single classroom can be of benefit to both individuals and the community (Yuan & Zhang, 2019). Primarily by engaging students and teachers as co-designers using Knowledge Forum, powerful innovations arise as Knowledge Building theory, pedagogy, and technology itself undergoes the process of idea improvement.

What are the pedagogical and technological designs for implementing Knowledge Building in classrooms?

Theory, pedagogy and technology are integral – Knowledge Building pedagogy is designed to help students experience how knowledge is created in innovative communities using online and offline discourse.

<u>Community Knowledge</u>

Disciplinary Knowledge Building is a collective endeavor. As Ford (2008) pointed out, "individuals do not construct scientific knowledge, communities do" (p. 269). Even in classrooms where extended inquiry and collaborative activities are common, there is a tendency to focus on investigations local to the individual or collaborative group, rather than working as a collective to build community knowledge. Cultivating Knowledge Building communities in classrooms involves pedagogical and technological designs that shift student inquiry from individual-level approaches (e.g., positioning a student as a biologist or an historian) to engaging students in inquiry at the *community level*, where research is undertaken as a joint enterprise (e.g.,

students participating in collective practices and social interactions across a community of biologists or historians). The pedagogical and technological designs for Knowledge Building communities focus on critical aspects such as building a shared identity (our collective purpose), supporting the development of shared practices and collective norms around sustained creative work with ideas (how we function), and the production of public knowledge continually improved by the community (what we produce and work to advance).

Online and offline works are intertwined in Knowledge Building classrooms, both emphasizing communal processes. The use of talk-based and physical communal knowledge spaces to complement collective work in the Knowledge Forum database can also be found in classroom implementations of the KBC models (e.g., Messina, 2001; Resendes, et al., 2015; Zhang, Hong, Scardamalia, Morley, & Teo, 2011). According to Bev Caswell, one of the teachers in these classrooms, the community discussions "reinforce the democratic approach to Knowledge Building and lay the foundation that ideas are to be respected" (Caswell & Bielaczyc, 2001, p.8). Other physical communal spaces in Knowledge Building classrooms have been created using large sheets of paper or wall space to lay out the community's knowledge work. Typically, such spaces provide a visible physical referent as a complement to the online work in Knowledge Forum, or as a means of exemplifying the power of communal Knowledge Building prior to introducing students to Knowledge Forum (e.g., Bielaczyc & Ow, 2014; Tao & Zhang, 2018).

Principle-Based Pedagogy

Knowledge Building pedagogy and technology work from guiding principles rather than prescribed procedures (Hong & Sullivan, 2009; Scardamalia, 2002; Zhang et al., 2011). Different from many inquiry-based pedagogy in which students work on pre-defined project, problems and specific tasks, "principle-based pedagogy" is emphasized. Principle-based approach focuses on developing workable principles that create the conditions that make the emergence of ideas more likely. Teachers and students co-construct the flow of inquiry as it unfolds and emerges, guided by a set of principles (Appendix 2). These principles provide teachers a way of talking about their understanding of Knowledge Building; they work as a system rather than separately as isolated principles. Knowledge Forum provides a knowledge-creation space for realizing these principles. Students work in opportunistic and flexible ways rather than following scripted activities. For example, the principle "epistemic agency" highlights students negotiating the fit between their own ideas and those of others. Teachers can encourage epistemic agency in different ways, such as having students initiate experiments to test their ideas, or having students engage in "Knowledge Building classroom talk" to contrast diverse and divergent ideas. The uses of these principles and related activities vary with the emergent questions and goals in the classroom community. Over the last three decades, a wealth of design-based classroom studies in Knowledge Building to explore how a principle-based pedagogy can improve student learning and depth of understanding (for a review, see Chen & Hong, 2016; Zhang et al., 2018). Below are several design considerations for creating a principle-based Knowledge Building classroom.

Design Considerations

*Emergent versus fixed curriculum***.** The key feature of a Knowledge Building classroom is to turn over high-level agency to students for sustained inquiry;

epistemic agency is central. A progressive and emergent curriculum is needed to support idea development and to maximize the opportunity for knowledge creation (Caswell & Bielaczyc, 2001; Zhang et al., 2007). Unlike pedagogy using well-developed curriculum and inquiry-based materials, Knowledge Building does not use pre-designed materials. Each Knowledge Building endeavour, spanning a few months, is situated within some curriculum area; however, it is the students who are taking cognitive responsibility for the curriculum working on driving questions and inquiries into the core concepts, similar to scientists engaged in inquiry. Caswell and Bielaczyc (2001) examined how children collectively pursued inquiries into the study of evolution using an emergent curriculum and discussed that the children's inquiries somewhat resembled the scientific progress to what Darwin did in his exploration. A Knowledge Building curriculum relies a great deal on the emerging interests of the participants, and community knowledge is important.

Idea-centered versus task-centered focus. Knowledge Building focuses on ideas and idea improvement. Students' ideas, rather than tasks, are viewed as the center of classroom life (Scardamalia, 2002). There are no prescribed routines; the goal is to improve the community's ideas. Knowledge Building pedagogy encourages students to enact high-level epistemic agency – to refine their knowledge goals progressively as their inquiries unfold and to contribute, advance and refine their collective ideas. Zhang et al. (2007) discussed the practices for idea improvement in a principle-based classroom. The students started with face-to-face discussions; different ideas were elicited and made public for improvement. Through both online and offline discourse, students pursued idea improvement: They formulated problems of understanding, set forth theories to be improved, identified constructive information, and compared different ideas and models. In line with design-mode thinking, the students continually refined and revised their ideas, hypotheses, and theories thereby deepening their explanations.

Rise-above and Meta-discourse. Central to innovative communities is reflection, rise-above, and concurrent assessment. Knowledge Building design involves a meta-level of discourse beyond problem-solving; rise-above is a key principle. Knowledge Building pedagogy involves classroom talk as a meta-discourse, with students "talking about their talk", discussing their conversation on Knowledge Forum. Students can collectively monitor the community's progress and identify new lines of inquiry. Van Aalst and Chan (2007) designed an e-portfolio assessment tool using a set of four Knowledge Building principles as the criteria to assess their collective advance on KF. Resendes et al. (2015) employed word-cloud visualization in formative assessment to help students conduct discourse about their KF work. Lei and Chan (2018) examined meta-discourse using KF reference notes and online/offline discourse considering what they have accomplished (e.g., "Putting our ideas together," "We now know … "); identify new questions and emergent goals (e.g., "We still could not understand why … "); design new questions (e.g., "Maybe we can look at this problem in a different way") and also reflect on KF progress (e.g., "Is our discussion going anywhere?"). Reflection and assessment helped the students engage in meta-discourse, synthesizing the best work of the community.

Fixed groups versus opportunistic groups. Small collaborative group design is common in CSCL pedagogy, but Knowledge Building emphasizes designing for distributed and collective advance in community knowledge. Zhang et al. (2009)

reported on a three-year design-based study of how a teacher changed his group collaboration structure within a Knowledge Building classroom. Children worked in fixed assigned groups in Year One, interactive fixed groups in Year Two, and opportunistic groups as a whole class in Year Three. As it turned out, the opportunistic grouping was most effective for both diffusion of ideas and scientific accuracy of ideas. Knowledge Forum allowed for inter-connected views for opportunistic groups to work with ideas creatively. The students could work on different problems in different views; new views could be created as other goals emerged, and the students could synthesize knowledge in rise-above views. Cross-groups and community-based groupings supported by technology increased the emergence of ideas. Such designs also reflected the kinds of knowledge-creation dynamics in scientific communities with emergent interaction of ideas.

Role of teachers. Comparison of three idealized models helps to depict the roles of teachers in Knowledge Building classrooms (Bereiter & Scardamalia, 1987b; cited in Chen & Hong, 2016). Teacher A is a "workbook" model common in schools, with teachers focusing on the routine of completing preset tasks and activities. Teacher B undertakes many good principles from the learning sciences (e.g., designs rich authentic problems, harnesses prior knowledge, and provides formative feedback) in his or her classroom. The Teacher C model, a Knowledge Building approach, includes these good features, but has Teacher C working to enable students to take over much of what Teacher B would do, but by carrying it out themselves. For example, rather than the teacher establishing authentic problems, the students may identify meaningful and cutting-edge problems of their community for investigation. Students are to carry out the executive functions for their progress not relying on teacher direction; epistemic agency and community knowledge key to progress. The teacher's role is to highlight the epistemic needs of students, helping them to "notice" what is significant in the community through modeling, co-reflection, and working as a fellow knowledge builder.

The websites included in the discussion paper (Appendix 3) include an array of exemplars of how Knowledge Building teachers in different countries have pursued Knowledge Building/knowledge creation to improve on their classroom practices. There are also various research programs examining the dynamics, processes, and outcomes of these designs; how these research and practical examples and evidence can be transformed into educational policies with implications are important questions for discussion.

How do teachers learn Knowledge Building? What are the strategies and challenges in teacher professional development?

While it may be easier to appreciate the arguments for adopting Knowledge Building pedagogy, many teachers still struggle with the design and implementation of Knowledge Building in classrooms. Implementing computer-supported collaborative learning is a complex process that involves multi-faceted factors, such as teachers' personal epistemology, task management, the potential impacts on students (van den Berg, 2002), and the difficulty of fostering collaborative learning in contemporary schools (Stahl, 2002). In CSCL and learning sciences, researchers have examined notions of teacher knowledge (Looi & Song, 2013), teachers as designers (Friesen & Jacobsen, 2015) and teacher professional communities as key themes (Fishman, Davis

& Chan, 2014). In Knowledge Building, research has shown some success with the principle-based approach (Zhang et al., 2011) in a Canadian elementary-school over an eight-year study. This principle-based approach departs from the procedural instructional design models with which teachers are more familiar. Teachers work together to think about the kind of interactions in their classes that puts students' ideas at the center of the classroom enterprise – they work to rationalize and translate their teaching practice in relation to Knowledge Building principles, which feature an interactive system that makes continual improvement of ideas possible. The importance of teachers working in communities using principle-based approaches supported by technology has also been examined in teacher learning about Knowledge Building in Hong Kong schools (Chan, 2011) and Singapore schools (Teo, 2019).

As is true of any serious innovation in educational practice, Knowledge Building has implications for teacher education and teacher development. The approach taken by virtually all Knowledge Building innovators has been to prepare teachers for it by engaging them in Knowledge Building among themselves. Chai and Tan (2009) reported a highly developed approach in which teachers used the spiral-of-knowing schema (Wells, 1999) over a sustained period. By linking a series of formal courses, practicing teachers engaged in identifying authentic problems in integrating ICT in schools, collaboratively designing Knowledge Building lessons that considered the challenges identified, and finally implementing the lessons. The formal courses provided opportunities for teachers to learn about the relevant theories and principles, as well as using the platform to discuss their authentic experiences and co-construct their solutions to the challenges. Chai and Tan reflected on the factors that worked well in their study: (1) committed teacher participants who worked well with one another; (2) solving authentic problems faced in schools as the learning objectives; (3) teachers' agency in problem-solving; (4) sustained inquiry and ample time for reflection and forming theory-practice links; and, (5) having a competent facilitator who was familiar with Knowledge Building.

Beyond formal courses, professional learning community (PLC) (DuFour, DuFour, Eaker, & Many, 2006) has been used to engage teachers in collaborative and authentic investigation of classroom practices that could have a direct impact on student learning (McLaughlin & Talbert, 2006). Tan, Chue, and Teo (2014) reported a study that examined how Knowledge Building was accomplished among teachers within a PLC. In this study, the teachers adopted Knowledge Building pedagogy for learning science and for essay writing. The study revealed a dual-layer of Knowledge Building: the collaborative Knowledge Building among the teachers that resulted in idea improvement and rising above the current practices, while the teachers focus on designing and facilitating Knowledge Building among students. The students' posts in the Knowledge Forum served as the material resources and common referents for the teacher's discussion. The common goal of helping students advance their ideas served as the joint enterprise of the teachers. Consequently, the PLC became a meaningful ground for professional learning among the teachers. By working with teachers in their classrooms, Teo and her collaborators (Chan, Teo, & Lee, 2016) have also documented how teachers could facilitate Knowledge Building in science and history classrooms.

Teo (2014) discussed Knowledge Building practice within a teacher community in Singapore, emphasizing teachers' continual improvement of practice while they foster continual improvement of students' ideas. Knowledge Building practice places students' ideas at the center of the classroom enterprise, focusing on getting students to take responsibility to improve ideas. A problem-space model involving different facets (i.e., curriculum/standards; social interaction; student capability; classroom structure and constraints; and technology) was developed to guide the investigation and provide a theoretically and empirically-based description of the shifts teachers undergo as they gain competence in Knowledge Building pedagogy. More recent work has examined symmetrical advances in the different layers and teachers using learning analytics to advance their Knowledge Building classroom practices.

Knowledge Building is a principle-based approach to teaching that departs quite drastically from status quo methods of instruction, thus requiring changes in teachers' epistemological and pedagogical beliefs. Tensions between scripted and non-scripted pedagogy (Bereiter et al., 2017) and the question of whether different teachers are more or less suited to conducting Knowledge Building need to be examined further. Discussing these challenges and identifying examples of how teachers from different cultural contexts adopt Knowledge Building would have useful implications for supporting teachers to become designers of innovative practices.

What are the enabling conditions for successful implementation and sustainability in schools and districts? How do we effectively build capacity within a system for scaling up Knowledge Building?

Successful implementation and sustainability of technology innovation in schools is a complex question. Critics have argued that the design research of learning scientists, which typically focuses on classrooms, has minimal impact on educational change because the "community leaves the job of scaling up and sustainability to other research communities" (p. 454, Wise & Schwarz, 2017). Learning scientists are now developing research-practice partnerships (Design-based implementation research) to develop long-term solutions for improving teaching and learning (Coburn & Penuel, 2016; Penuel et al., 2011). A growing body of work demonstrates that school-university-government partnerships (e.g., Laferrière, et al., 2010; Chan, 2011) and multi-level networks (e.g., Teo, 2019; Ma, Resendes, Scardamalia, & Dobbie, 2019) are powerful mechanisms for building capacity as well as spreading Knowledge Building innovations within a system. These studies indicate that the process of scaling up is neither completely top-down nor bottom-up driven, but rather an ongoing conversation between researchers, teachers, administrators, system leaders – and even students – working together in design mode to advance the frontiers of educational practices.

Much like in high-performing school systems where teachers are afforded high levels of autonomy and provided with opportunities to collaborate (Schleier, 2018), scaling up Knowledge Building is taken up as a collective responsibility by educators at all levels. System leaders create alignment between Knowledge Building and other educational initiatives, such as 21st century competencies and workplace skills development. Administrators create failure-safe cultures in their schools to encourage teachers to experiment with their practices. Teachers work with students to design power socio-technical systems that generate novel and meaningful ways for students

to self-organize around idea improvement. Researchers work with teachers to document the iterative design process and identify powerful practices that link to student outcomes. Finally, regular meetings between all these stakeholders at local and international design sessions to facilitate symmetric knowledge advances across sites, while growing the social capital of these innovation networks. These meetings provide opportunities for researchers and educators to harvest new ideas, engage in cross-fertilization of ideas, and identify new design challenges—all of which are critical to evolving the system's theory of action, while sustaining educators' epistemic agency.

Learning and continuous improvement happen at all levels of the system, as educators go beyond building collective efficacy (for instruction) and move toward building collective capacity for innovation. Teachers and students themselves become creators of new knowledge. In this way, Knowledge Building, as an educational initiative, aims to bring schools to the center of knowledge societies (UNESCO, 2005) and cultivate students to be not only lifelong learners, but also lifelong innovators empowered to tackle wicked problems that are yet to come (Scardamalia & Bereiter, 2016).

School-university-government partnerships have been a major approach to scaling and sustaining KB practice. For example, in Canada, the TeleLearning Network of Centres of Excellence built university-school partnerships at four sites (Vancouver, Toronto, Montreal, and Quebec City) to reduce the gap between research and practice, an important use of ICT in education and teacher professional development. Laferrière (2017) examined two case studies across 2004-2009: the first one involving two universities and schools as partner institutions at Barcelona and networks of schools using Knowledge Forum and KB principles, and the second case involving three universities and 50 remote rural schools in Quebec. Analyses show key partnership dynamics and enabling conditions—Knowledge Building as shared vision, symmetrical knowledge advancement, and multi-level research-based innovation. In the Remote Networked School initiative (Quebec, Canada), much attention was given to innovation conditions (Ely, 1999; Hamel, Turcotte, & Laferrière, 2013), as well as design-based research in combination with cultural-historical activity theory (CHAT, Engeström, 1987; 2014) for increasingly successful design iterations.

The Knowledge Building community model is an international movement now developing in over twenty countries in classrooms, schools, extending to school systems and global communities. Knowledge Building International, (formerly Knowledge Society Network) includes a global network of researchers, teachers, school leaders, policy makers, and engineers working together and meeting regularly in Summer Institutes and other events, creating knowledge about Knowledge Building. As an example of a dynamic, globally networked Knowledge Building community, participants have contributed to a multi-nation design experiment in Knowledge Forum to explore challenges and test possibilities for innovation in education (Hong, Scardamalia, & Zhang, 2010). Continued developments are currently taking place in Knowledge Building International in the collective pursuit of advancing the role of Knowledge Building in education through design, practice, and policy impact.

Research Impact, Challenges and Moving Forward

As a pioneering model of CSCL, Knowledge Building continues to be a prominent research area synergizing theory, technology and pedagogy with increasing implementation in different countries. A key question for strategic alignment between research and policy pertains to the research evidence for educational effectiveness and impact on student learning. Knowledge Building has been examined in diverse curricular areas including (but not limited to): science (Zhang et al. 2007; 2018), math (Moss & Beatty, 2006; 2010), literacy (Zhang & Sun, 2011), history (Resendes & Chuy, 2010; Chan, Teo, Lee, 2016), geography (Lee, Chan & van Aalst, 2006), chemistry (Chan, Lam, & Leung, 2012), coding (Milinovich & Ma, 2018), and visual arts (Yang, Chan, & van Aalst, 2016). While the longstanding research tradition generally emphasizes collective knowledge growth, an emerging set of studies are shedding light on the positive effects of both collective advances and individual learning processes and outcomes. Positive learning gains have been obtained in science and scientific literacy (Chuy, et al., 2011; Lee, Chan, & van Aalst, 2006; Zhang, et al., 2007); vocabulary and literacy (Sun, Zhang, & Scardamalia, 2009; Chen, et al., 2015), historical reasoning (Chuy, Resendes, & Scardamalia, 2010), graphic literacy (Gan, Scardamalia, Hong, & Zhang, 2010). Analysis of literacy and text reading shows how Knowledge Forum students consistently perform above their grade level (Sun, Zhang & Scardamalia, 2010).

Comparative and evaluation studies have shown that CSILE students outperform comparison groups on standardized tests on language and literacy, with these advantages persisting over years (Scardamalia *et al.*, 1992). In Asian countries where academic achievements are crucial, researchers have shown positive effects examining student knowledge using national curriculum standards (Oshima *et al.*, 2004). Students outperformed their counterparts on public examination results when their teacher integrated the socio-metacognitive aspects of knowledge-creation approach with the socio-cultural milieu of the Asian classroom (Chan, 2008; Lam & Chan, 2013; Lin, Hong, & Ma, 2019). Different examples of the effects of Knowledge Building on learning outcomes can be found in review studies of Knowledge Building (see Chan, 2013; Chen & Hong, 2016 for reviews).

Knowledge building has also been conducted for diverse learners including preschool children (Pelletier, Reeve, & Haywood, 2010; Tarchi et al., 2013), indigenous students (McAuley, 2010), tertiary students (de Jong, Veldhuis-Diermanse, & Lutgens, 2002), preservice teachers (Hong, Lin, Chai, Hung, & Zhang, 2019), vocational students (van Heijst, de Jong, van Aalst, de Hoog, & Kirschner, 2019), and medical health practitioners (Russell & Perris, 2003: Lax, Scardamalia, Watt-Watson, Hunter, & Bereiter; Singh, Kim, & Mazzotta, 2016). Although it is a common belief that Knowledge Building would only work for high-ability students, recent studies have shown how Knowledge Building supports the development of metacognition and domain knowledge for academically-low-achieving students (Yang, van Aalst, & Chan, 2019).

The current review seeks to highlight key themes and issues and research examples that may enrich our inquiry into knowledge creation in classrooms and schools and global communities. This group will work further to identify challenges for the next

decade of Knowledge Building research, in particular identifying examples that depict knowledge creation and to examine the alignments of theories, practice and research, with policy linking to different frameworks for advancement in theory-practice-policy synergy.

Questions for Discussion

- How can Knowledge Building/knowledge creation generate new alignments with educational practices, frameworks and policies to strengthen synergies between theory, pedagogy, technology, and policy?
- In what ways does Knowledge Building support students in developing 21st century competencies and beyond?
- How can we expand and use the research evidence of Knowledge Building to impact educational policy and practice?
- How can we develop criteria for identifying exemplars of knowledge creation to enrich theory and design and to support teacher learning and classroom practice?
- How can we help teachers change their pedagogical beliefs and practices? How can we help them seek alignment between KB and school curriculum and assessment?
- How can we advance the design of Knowledge Building technologies to promote better interoperability across platforms while taking advantage of new affordances of Web 3.0?
- What are the enabling conditions for fostering innovation networks in school systems for scaling and sustaining Knowledge Building?
- How can we develop global innovation networks of Knowledge Building? How can we design a Knowledge Building collaboratory to promote cross-community interactions and new forms of knowledge creation?

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Appendix 1

Twenty-first-century competences experienced in Knowledge Building communities

21st-century skills	**Characteristics of knowledge-creating organizations**	
	Entry level	High
Creativity and innovation	Internalize given information; beliefs/actions based on the assumption that someone else has the answer or knows the truth; creativity as individual endeavors	Work on unsolved problems; generate theories and models, take risks, etc.; pursue promising ideas and plans.
Communication	Social chit-chat; discourse that aims to get everyone to some predetermined point; limited context for peer-to-peer or extended interactions.	Discourse aimed at advancing the state of the field; to achieve a more inclusive, higher-order analysis; open spaces encourage peer-to-peer and extended interactions.

Collaboration/ teamwork	Small group work: divided responsibility to create a finished product; the whole is the sum of its parts, not greater than that sum.	Shared intelligence from collaboration and competition enhances existing knowledge. Individuals interact productively and work with networked ICT. Advances in community knowledge are prized over individual success, while enabling each contributes to it.
Information literacy/ research	Inquiry: question-answer, through finding and compiling information; variable testing research.	Collaborative expansion of the social pool of improvable ideas, with research integral to efforts to advance knowledge.
Critical thinking, problem solving and decision- making	Meaningful activities designed by the director, teacher or curriculum designer; learners work on predetermined tasks set by others.	High-level thinking skills exercised in authentic knowledge work; the bar for accomplishments is continually raised by participants as they engage in complex problems and systems thinking.
Citizenship-local and global	Support of organization and community behavioral norms; “doing one’s best”; personal rights.	Citizens feel part of a knowledge-creating civilization and aim to contribute to a global enterprise; they value diverse perspectives, build shared knowledge in formal and informal settings, exercise leadership, and support inclusive rights.
ICT literacy	Familiarity with and ability to use common applications and web resources and facilities.	ICT integrated into organization’s daily work; shared community spaces built and continually improved by participants, with connections worldwide.
Life and career skills	Personal career goals are consistent with individual characteristics; realistic assessment of requirements and probabilities of achieving career goals.	Engagement in continuous, “lifelong” and “life-wide” learning opportunities; self-identification as a knowledge creator, regardless of life circumstance or context.
Learning to learn / metacognition	Students and workers provide input to the organization, but the high-level processes are under the control of someone else.	Students and workers are able to take charge at the highest executive levels; assessment is integral to the operation of the organization, requiring social as well as individual metacognition.

Personal and social responsibility - incl. cultural competence	Individual responsibility; local context.	Team members build on and improve the knowledge assets of the community, with appreciating cultural dynamics that allow the ideas to be used and improved for the benefit of multicultural, multilingual, changing society.

From Scardamalia, M., Bransford, J., Kozma, R., & Quellmalz, E. (2012). New assessments and environments for knowledge building. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 231 - 300). Springer, Dordrecht.

Appendix 2

Socio-cognitive and technological dynamics of Knowledge Building principles

REAL IDEAS, AUTHENTIC PROBLEMS
Socio-cognitive dynamics: Knowledge problems arise from efforts to understand the world. Ideas produced or appropriated are as real as things touched and felt.
Technological dynamics: *Knowledge Forum* creates a culture for creative work with ideas. Notes and views serve as direct reflections of the core work of the organization and of the ideas of its creators.

IMPROVABLE IDEAS
Socio-cognitive dynamics: All ideas are treated as improvable. Participants work continuously to improve the quality, coherence, and utility of ideas.
Technological dynamics: *Knowledge Forum* supports recursion in all aspects of its design—there is always a higher level, there is always opportunity to revise.

IDEA DIVERSITY
Socio-cognitive dynamics: Idea diversity is essential to the development of knowledge advancement. To understand an idea is to understand the ideas that surround it, including those that stand in contrast to it.
Technological dynamics: *Knowledge Forum facilitates* linking ideas and bringing different combinations of ideas together in different notes and views, promotiing the interaction that makes productive use of diversity.

RISE ABOVE
Socio-cognitive dynamics: Creative knowledge building entails working toward more inclusive principles and higher-level formulations of problems. It means learning to work with diversity, complexity and messiness, and out of that achieve new syntheses.
Technological dynamics:. Rise-above notes and views in Knowledge Forum support unlimited embedding of ideas in increasingly advanced structures, and support emergent rather than fixed goals.

EPISTEMIC AGENCY
Socio-cognitive dynamics: Participants set forth their ideas and negotiate a fit between personal ideas and ideas of others, using contrasts to spark and sustain knowledge advancement. They deal with problems of goals, motivation, evaluation, and long-range planning that are normally left to teachers or managers.
Technological dynamics: *Knowledge Forum* provides support for theory construction and refinement and for viewing ideas in the context of related but different ideas. Scaffolds for high level knowledge processes are reflected in the use and variety of epistemological terms (such as

conjecture, wonder, hypothesize, and so forth), and in the corresponding growth in conceptual content.

COMMUNITY KNOWLEDGE, COLLECTIVE RESPONSIBILITY
Socio-cognitive dynamics: Contributions to shared, top-level goals of the organization are prized and rewarded as much as individual achievements. Team members produce ideas of value to others and share responsibility for the overall advancement of knowledge in the community.
Technological dynamics: *Knowledge Forum's* open, collaborative workspace holds conceptual artifacts that are contributed by community members. Community membership is defined in terms of reading and building-on the notes of others; linking views in ways that demonstrate view interrelationships; all participants share responsibility for the highest levels of the organization's knowledge work.

DEMOCRATIZING KNOWLEDGE
Socio-cognitive dynamics: All participants are legitimate contributors to the shared goals of the community; all take pride in knowledge advances achieved by the group. The diversity and divisional differences represented in any organization do not lead to separations along knowledge have/have-not or innovator/non-innovator lines. All are empowered to engage in knowledge innovation.
Technological dynamics: There is a way into the central knowledge space for all participants; analytic tools allow participants to assess evenness of contributions and other indicators of the extent to which all members do their part in a joint enterprise.

SYMMETRIC KNOWLEDGE ADVANCEMENT
Socio-cognitive dynamics: Expertise is distributed within and between communities. Symmetry in knowledge advancement results from knowledge exchange and from the fact that to give knowledge is to get knowledge.
Technological dynamics: *Knowledge Forum* supports virtual visits and the co-construction of views across teams, both within and between communities. Extended communities serve to embed ideas in increasingly broad social contexts. Symmetry in knowledge work is directly reflected in the flow and reworking of information across views and databases of different teams and communities.

PERVASIVE KNOWLEDGE BUILDING
Socio-cognitive dynamics: Knowledge building is not confined to particular occasions or subjects but pervades mental life—in and out of school.
Technological dynamics: *Knowledge Forum* encourages knowledge building as the central and guiding force of the community's mission, not as an add-on. Contributions to collective resources reflect all aspects of knowledge work.

CONSTRUCTIVE USES OF AUTHORITATIVE SOURCES
Socio-cognitive dynamics: To know a discipline is to be in touch with the present state and growing edge of knowledge in the field. This requires respect and understanding of authoritative sources, combined with a critical stance toward them.
Technological dynamics: *Knowledge Forum* encourages participants to use authoritative sources, along with other information sources, as data for their own knowledge building and idea-improving processes. Participants are encouraged to contribute new information to central resources, to reference and build-on authoritative sources; bibliographies are generated automatically from referenced resources.

KNOWLEDGE BUILDING DISCOURSE
Socio-cognitive dynamics: The discourse of knowledge building communities results in more than the sharing of knowledge; the knowledge itself is refined and transformed through the discursive practices of the community—practices that have the advancement of knowledge as their explicit goal.
Technological dynamics: *Knowledge Forum* supports rich intertextual and interteam notes and views and emergent rather than predetermined goals and workspaces. Revision, reference, and annotation further encourage participants to identify shared problems and gaps in understanding and to advance understanding beyond the level of the most knowledgeable individual.

EMBEDDED AND TRANSFORMATIVE ASSESSMENT
Socio-cognitive dynamics: Assessment is part of the effort to advance knowledge—it is used to identify problems as the work proceeds and is embedded in the day-to-day workings of the organization. The community engages in its own internal assessment, which is both more fine-tuned and rigorous than external assessment, and serves to ensure that the community's work will exceed the expectations of external assessors.
Technological dynamics: Standards and benchmarks are objects of discourse in *Knowledge Forum*, to be annotated, built on, and risen above. Increases in literacy, twenty-first-century skills, and productivity are by-products of mainline knowledge work, and advance in parallel.

From Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.

Appendix 3

Video Resources and Websites

- Scardamalia, M. & Bereiter, C. (2016). Knowledge building: Communities working with ideas in design mode [Webinar]. In NAPLeS video series. Retrieved from http://isls-naples.psy.lmu.de/intro/all-webinars/scardamalia-bereiter/index.html

- Knowledge Building – Ontario
  thelearningexchange.ca/itl-project-home/itl-project-knowledge-building
- Knowledge Building – Singapore
  https://www.kbsingapore.org/
- Knowledge Building – New Zealand
  https://sites.google.com/netnz.org/kbnz/home
- Knowledge Building International Project
  http://kbinaction.com/KBIPindex.html
- Knowledge Building Summer Institute
  http://ikit.org/kbi/index.php/summer-institutes/
- Knowledge Building International
  https://us17.campaign-archive.com/home/?u=4ccdc9118bb28e4535b5f3c00&id=349409e726