Title	Knowledge building: Aligning education with needs for knowledge creation in the digital age
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Knowledge Building: Aligning education with needs for knowledge creation in the Digital Age

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Abstract:

This paper examines the alignment of education with the needs for knowledge creation in the digital age using the Knowledge Building model and Knowledge Forum® technology. Knowledge Building is akin to knowledge creation as practiced in research laboratories and other frontier-advancing organizations, with added focus on value to the individual, community, and society. Knowledge Forum has evolved with theory and pedagogy over the years, and makes knowledge-creation processes available to school-aged students. Despite reform efforts, misalignments for educational innovation continue to prevail in schooling, and changes often create more disruptions. Without a coherent framework and sustained progressive change, innovations may fail to make their way into policy and practice, creating an endless catching-up game and fragmentation at different levels. This paper draws from the Knowledge Building model and research to discuss alignments for knowledge creation in seven areas: (1) views of knowledge; (2) 21st-century educational competencies; (3) education and equity; (4) pedagogy and technology integration; (5) assessment, learning and collaboration; (6) teacher learning; and (7) student learning outcomes. Through decades of sustained design implementation research, using a systemic approach involving school-university-government alliances and globally distributed hubs of innovation, Knowledge Building teams have engaged in the reconstruction of educational practices to establish self-improving systems for continual alignments in knowledge creation. The mobilization of educational stakeholders worldwide, such as the EduSummIT, provides opportunities for bridging research and practice and educational improvements. Implications of Knowledge Building for developing self-improving systems and communities that leverage technology for realigning education in knowledge creation are discussed.

Keywords:

Knowledge Building, Knowledge Creation, Technology-Supported Environments, Educational Alignment, Digital Age

The growing need for innovation and knowledge creation driven by global developmental goals requires wide participation in knowledge production and

utilization (UNESCO 2005; OECD 2013). This has led to calls for educational reform across the world, with nations exploring how to create school systems aligned with shifts to a knowledge society. Not surprisingly, these reforms face many challenges, including social and economic challenges of re-tooling and re-training, particularly with quickly-evolving digital technologies constantly altering the landscape of professional and personal life. However, even with robust economic and socio-technical supports for educational reform, we believe that the real key to addressing education in the knowledge age lies in how these reforms are framed.

To cultivate the types of educational systems that build human capacity for innovation and knowledge creation, there needs to be a break from framing schooling as "preparing students for the knowledge society," where educational systems examine future economic opportunities in relatively stable societies and work backward from a list of desired adult skill sets and competencies. While this framing has a logic that has proved useful in the past, the 21st-century knowledge society is defined by uncertainty, unprecedented knowledge and technological advances, and far-reaching global changes. Thus, even if all school systems were to adopt the most recent evidence-based curriculum and assessments, train their teachers in the latest "best practices," install the latest, most flexible technology-based tools and so on, they would enter a never-ending race of adoption-adaption in the hope of not falling behind an ever-advancing "cutting edge." A further complication in framing school change around "preparing students for the knowledge society" is that it positions schools only as innovation-adopters, not as innovative, knowledge-creating organizations themselves. If educational institutions within a society are not themselves centers of innovation and

knowledge creation, then the production and utilization of new knowledge is neither pervasive nor rewarding.

In this paper, we explore an alternative framing centered on "schooling as participating in the work of society" with schools as knowledge-creating communities in their own right. The proposed participatory approach using technology extends beyond students to include teachers and other educational stakeholders throughout the system as active participants in knowledge creation.

Setting the stage – Education for knowledge creation in the Digital Age

The 21st Century is characterized by knowledge creation and innovation where the creation, dissemination, and utilization of new knowledge are central to the advancement of nations. While in the Industrial Age, physical assets, manual labor, and tangible commodities are valued, in the Knowledge Age, new knowledge becomes an advanced form of capital that can determine the health and wealth of a nation (OECD 2013).

A parallel development in the 21st Century is the rapid advancement in digital technologies. Social networking software has changed the fundamental ways we communicate, receive information, learn and work with others (Tan & Lee 2018), while high-speed wireless networks, mobile personal devices, and cloud computing have dramatically changed our everyday lives. These tools allow us to connect in unprecedented ways and to capitalize on user-generated knowledge in worldwide communities to create new forms of collective engagement with epistemic artifacts.

The confluence of knowledge societies and fast-paced changes in digital technologies create ripple effects within societies. The rise of artificial

intelligence, novel data mining techniques and the melding of data across physical and cyberspace have and will continue to disrupt job markets as information processing and technical tasks become offloaded to machines (World Economic Forum 2018). Moreover, the shortening shelf-life of specific content knowledge further reinforces the centrality of knowledge work in modern society.

Taken together, changes within society, as we see now reflected in a pandemic, combine with fast-paced technological changes, highlight the need for different pedagogy and technology in schools (Anderson 2008; Sawyer 2014). The notion of knowledge creation as an education goal is stressed in the educational documents of major global education organizations (see UNESCO ICT competency framework for teachers, UNESCO 2011) and there is growing recognition that schools need to develop a culture of creativity and innovation to adapt to the needs of knowledge societies (Pellegrino & Hilton 2013). As part of schooling, students need to develop the dispositions and capacities to work creatively with ideas – to become knowledge creators.

Despite continuous reform efforts to bring education into the Knowledge Age (UNESCO 2011), school systems across the globe continue to face challenges enacting education policies that become part of school practices. Reforms commonly rely on linear input-process-output models to replicate "best practices" (Hargreaves 2003). However, education reform and technology innovation are complex problems that cannot be reduced into separate, manageable components. Educational reform requires a social distribution of knowledge to build capacity within the system. Furthermore, implementing evidence-based practices must consider contextual factors through dialogic engagement between researchers and participants (Gibbons et al. 2010). The transdisciplinary mobilization of knowledge to different stakeholders can be

supported through use-inspired research (Stokes 1997) and user-generated innovations (von Hippel 2005). Sustainable educational change, therefore, requires holistic, agile approaches that accommodate and increment innovations in practice, while creating new knowledge that informs and shapes the system through a process of continual improvement.

In this paper, we discuss issues that limit reforms; specifically, misalignments within the system that need to be redressed if education is to foster knowledge creation. We ground our discussion of the needed alignments using the Knowledge Building model created by Scardamalia and Bereiter and their colleagues in the 1990s. Knowledge Building represents "long running design experiments in education" (Bereiter, 2005/2006, p.18). We chose this model because it centers on a participatory approach involving educational stakeholders across the system as active creators of knowledge. While concerns are often expressed regarding contradictions between the time needed to advance basic skills and time committed to 21st-century competencies, Knowledge Building aims to address this challenge through an integrative model of basic skills as part and parcel of contributing ideas to a community resource supported by Knowledge Forum technology. Literacy is supported through meaningful contexts enhanced through interactions with community members. This model has a wide international footprint, including Ministry involvement and school-system implementations on several continents (Laferrière et al. 2015), and is also supported with rich research evidence spanning three decades (Chen & Hong 2016).

Knowledge Building Model

Knowledge Building, supported by Knowledge Forum® technology (Fig 1), is an educational model that aims to bring knowledge creation into schools by the most direct means possible - engaging students in the actual work of a knowledge society (Scardamalia & Bereiter 2014). Drawing on Popper's (1972) theory of objective knowledge, Scardamalia and Bereiter distinguish between learning and Knowledge Building – whereas the former refers to internal, individual changes of mind (World 2), the latter refers to the improvement and creation of *public knowledge* (World 3). Scardamalia and Bereiter (2014) propose bringing World 3 to the classroom and argue for an education agenda that will help children see their work as part of a civilization-wide effort to create and to advance knowledge.

While Knowledge Building serves as a pedagogical approach for the Knowledge Age, at its core is an epistemological theory about how new knowledge is generated in knowledge-creating communities through sustained collective inquiry, theory building, and evolution of thought. Similar to communities of scientists, designers, expert medical teams and so forth, members of Knowledge Building communities work together to tackle problems of understanding, identify and pursue promising ideas, develop and revise theories and explanations, generate and create new knowledge for the community, and refine work based on coherence and utility in new contexts.

A set of twelve principles have been postulated both to depict the socio-technological dynamics of effective knowledge creating communities and to guide classroom pedagogical design (Scardamalia 2002). For example, the principles of *real ideas for authentic problems, epistemic agency, idea diversity, improvable ideas, constructive use of authoritative sources*, and *rise above* point to different

facets of sustained inquiry and continuous improvement to drive the quality and utility of ideas. The principles of *Knowledge Building discourse, collective responsibility for community knowledge, democratizing knowledge, embedded and transformative assessment* emphasize community dynamics and meta-discourse that enable collaborative knowledge building. The principles of *pervasive Knowledge Building* and *symmetrical knowledge advancement* highlight the interdisciplinary nature of knowledge work for community knowledge advance and extensibility of work to a broader network of communities. These principles can be applied to any knowledge-creating enterprise – from professional organizations to K-12 schools.

Knowledge Building pedagogy is principle-based rather than following script-like activities. Students work on big questions (e.g., Why do civilizations rise and fall?) and collaboratively pursue idea development through collective epistemic agency and improvable discourse. Ideas, questions, and explanations are put forth in a public space, such as Knowledge Forum, for others to build on, revise, and expand for "rise above" and sustained idea development. Unlike collaborative group work with pre-set curriculum goals often found in technology-enhanced classrooms, participants seek out diverse views, assess promising ideas, examine explanations and redefine problems for theory building. Knowledge Building principle-based pedagogy involves students in advancing the frontier of collective knowledge.

Knowledge Forum, and its predecessor Computer-Supported Intentional Learning Environment (CSILE), are the first digitally networked platforms designed for collaborative Knowledge Building, and Knowledge Forum is currently the most widely used technology for knowledge creation in education (Wu & Wang 2016). Central to it is a community workspace where participants

contribute questions, ideas, theories and visualize how their ideas evolve. Knowledge Forum allows students to construct a communal multimedia database whereby knowledge artifacts are both visible and available for collective knowledge advancement. Embedded Knowledge Forum analytic tools support self- and group-assessment of the state of collective understanding so students can work as epistemic agents, identifying gaps in their community knowledge.

As an example, Figure 1 shows the discussion of a Grade Three class studying growth and change in plants, with initial big questions like "can plants grow without leaves?" and "why do plants eat carbon dioxide?". Students posted their ideas and questions on the view (Fig 1a) and wrote notes using scaffolds (e.g., I need to understand, my theory). To encourage multiple points of entry into Knowledge Forum, they used graphics and multimedia-rich objects to represent ideas (e.g., diagrams, audio notes). In this example, children integrated authoritative sources, such as videos and articles from NASA, into their online discussions to deepen collective understanding and spark new cycles of theory development, which evolved to include a range of advanced scientific concepts like cellular structures in plants, chemical exchange during photosynthesis, and carbon absorption on earth. Analytic tools in Knowledge Forum such as word-clouds showed how the students moved from the initial use of keywords such as 'root', 'stem', and 'water' to scientific words such as 'glucose' and 'stomata' (Fig 1c). Social network analysis (SNA) tools showed students building on one another's ideas with the teacher co-inquiring as a member of the community. Further analysis based on the SNA network showed that students took the lead of the discourse at different times suggesting collective cognitive responsibility for knowledge advancement (Fig 1d).

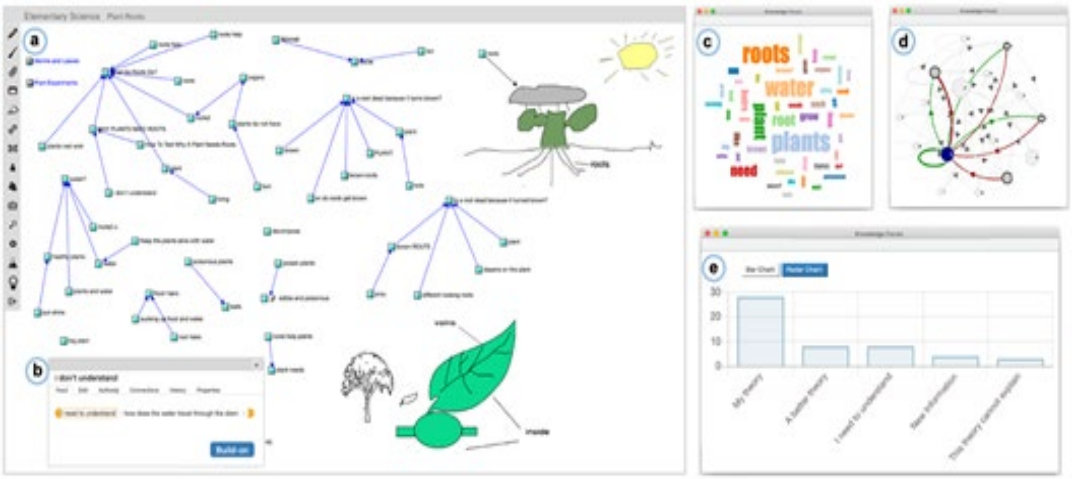

Fig 1. a) A typical view in Knowledge Forum with graphics, build on notes, links to other views; b) scaffolds for note writing, and analytics tools including c) word cloud, d) social network analysis, and e) scaffold growth. (Adapted from Chan et al. 2020).

Through integrated theory, pedagogy and technology, Knowledge Building aims to engage students of all ages and abilities in creative knowledge work. Principle-based pedagogy enables the enactment of authentic knowledge-creation processes while Knowledge Forum technology provides the affordances for instantiating them. Knowledge Building has undergone continual development with research progress in theory, design, principles, practices, and technology (Chen & Hong, 2016) and implementation in multi-level, multi-nation networks for scaling innovation in school systems (Laferrière et al. 2010). We propose that this model offers promising insights for addressing misalignments in schooling for the Knowledge Age, while opening new areas for research to advance educational policy and practice.

Misalignment and re-emerging alignment through Knowledge Building

Misalignments are prevalent in schooling due to problems with new forms of knowledge, human-computer interaction, changing leadership patterns, and

influences from technology (Cox & Laferrière 2019). Oftentimes, multiple tensions arise between curriculum, pedagogy, technology, assessment and school policy (Voogt & Pareja Roblin 2012). Misalignments do not merely refer to the contrasts between traditional classroom practices and adoption of new pedagogy and tools, but also the wide gaps between research and practice –tensions among professed goals, pedagogical intentions, school policies, and enacted practices at different dimensions and levels. Therefore, education reforms using piecemeal and ad-hoc changes risk the creation of even more misalignments and fractures in the school system.

The Knowledge Building model addresses misalignments through grounding in theoretical constructs of knowledge creation, with an overarching emphasis on bringing coherence to components at different levels of the education system. This model works to produce a coherent whole, attempting to identify and address different sources of alignment and misalignments of current practices for education for knowledge creation. We discuss seven areas: (1) views of knowledge, (2) 21st-century education, (3) education and equity; (4) pedagogy and technology integration (5) assessment, learning and collaboration, (6) teacher learning, and (7) student learning outcomes (Fig 2). We then explain the synergistic approach of the model and examples for advancement in school systems in the next section.

Misalignments with Knowledge Creation	Knowledge Building Emerging Alignments	Key Studies
	Epistemology and Views of Learning	
Gaps between professed educational goals and prevalent views of learning; learning to acquire what already exists and knowledge as immutable.	KB is conceptualized as learning for knowledge creation; KB is dynamic and part of a cultural effort engaging all students for sustained idea improvement through collective responsibility	Chen & Hong (2016); Chuy et al. (2011); Hakkarainen (2003); Tao & Zhang (2018); Tarchi et al. (2013); Zhang et al. (2007)
	Developing 21st Century Educational Competencies	
21st century learning is advocated, but the focus is often on mastering discrete skills as add-ons to the core curriculum, with knowledge-skill bifurcation.	KB goes beyond 21st century skills – competence emerges from student engagement in authentic knowledge-creation environments	Ma, Matsuzawa, & Scardamalia (2016); Scardamalia et al. (2012); Yang, van Aalst & Chan (2019)
	Educational for all and Equity	
Knowledge creation is for the privileged - only high achievers and capable students can do it	Knowledge creation is for everyone – all students can contribute and improve ideas; students of diverse backgrounds build knowledge together	Moss & Beatty (2010); Niu & van Aalst (2009); So, Seah, and Toh-Heng (2010); Yang, van Aalst & Chan (2019)
	Pedagogy and Technology Integration	
Overly scripted approach to pedagogies and new technologies -- generic digital tools and new pedagogies are add-ons, increasing work and to-do lists and favouring instructional procedures versus principles.	KB principle-based pedagogy integrated with Knowledge Forum technology optimized for the emergence of knowledge creation in a classroom; open-ended collective inquiry and technology designs guided by principles; student agency highlighted and pervasive change in classroom culture.	Caswell & Bielaczyc (2001); Resendes et al., (2015); Scardamalia et al. (1992); Zhang et al., (2009)
	Assessment, Learning and Collaboration	
Separation in learning and assessment: collaborative learning activities are common now but disconnected from the assessment that continues to emphasize individual-based achievement.	KB assessment illuminates learning and collaboration as it proceeds; embedded, concurrent, transformative assessment is supported by Knowledge Forum collaborative technology and analytics.	Chen & Zhang (2016); Lei & Chan (2018); van Aalst & Chan (2007); Resendes et al (2015); Zhang et al. (2018)
	Teacher Professional Development	
Professional learning is viewed as acquiring "best practices" from experts—often reflected in "one-and-done" workshops; pedagogy for improving learning is a process of individual change.	KB teacher professional development mirrors knowledge-creation processes fostered at all levels; thus teachers work collectively to progressively improve pedagogical designs for collective Knowledge Building.	Chan (2011);-Laferrière, Hamel, & Allaire (2013); Laferrière (2018); Tan et al. (2016); Teo (2014); Zhang et al. (2011)
	Student Learning Outcomes	
Common beliefs that higher-order thinking and knowledge creation approaches take up teaching time and do not benefit academic achievement	KB Studies showing student learning outcomes in different subject areas and levels -- students performing better or just as well for 'no-harm' principle; collective work bootstraps individual learning beyond curricular expectations	Chan, Lam, & Leung (2012); CJLT Special Issue (2010); Scardamalia et al. (1992)

Fig 2. Areas of misalignments for knowledge creation in schools and emerging realignments through Knowledge Building

Epistemology and views of learning

Despite major advances in constructivist theories highlighting students' active roles in knowledge construction (Jonassen 1999) and socio-cultural views on the development of expertise through participation (Lave & Wenger 1991; Sfard 1998), the current view of learning emphasizes acquisition of knowledge, where knowledge refers to entities stored in individual minds. The general belief is that knowledge creation proceeds after learning and is for knowledgeable elites. Although technology has been widely advocated in schools around the world, classroom designs are often premised on inadequate views of learning and knowledge (Chan & Yang 2018).

Beyond the constructivist and participation views in depicting learning, Paavola, Lipponen and Hakkarainen (2004) argue that learning needs to be broadened to emphasize community goals and dynamics in creating and advancing knowledge. The trialogical theory of knowledge creation (Paavola & Hakkarainen 2014) is particularly relevant in the Knowledge Age where the generation of new knowledge is prized. Knowledge Building theory and pedagogy, supported by Knowledge Forum, is distinctive with its focus on how children can create new knowledge, beyond learning what is already known.

Creating community knowledge is critical to the advancement of a knowledge society. Disciplinary knowledge creation has been a collective endeavor and a cultural effort, as epitomized in Ford's (2008) insights of scientific practices: "individuals do not construct scientific knowledge, communities do" (p. 269). In a knowledge building classroom, it involves shifting student inquiry from question-answer to sustained inquiry at the community level, where knowledge building is a joint enterprise to achieve new levels of understanding beyond what could be accomplished alone. As in knowledge-creating

communities, students add value to and extend frontiers of knowledge in their communities (Scardamalia & Bereiter 2014).

Scardamalia and Bereiter (2014) advocate an epistemology of collective responsibility for advancing community knowledge, with individual achievement as a result but not the focus. They asked, "Can children create knowledge" and used a variety of examples to illustrate that creative knowledge work is possible even among young children (Bereiter & Scardamalia 2010; Tarchi et al. 2013). They focus on the production of epistemic artifacts that enable further knowledge generation, with value beyond the immediate situation, as in the world beyond schools (Bereiter & Scardamalia 2010). Similarly, children engage in creative turns of mind that drive community knowledge forward and show markers of knowledge creation found in innovation networks (Ma, Matsuzawa, & Scardamalia 2016).

The literature on Knowledge Building in the last three decades shows that school-aged children develop theory-based epistemic perspective regarding scientific progress and knowledge advancement (Chuy et al. 2011; Lin & Chan 2018), shift to more sophisticated epistemic beliefs (Chen 2017), set community goals that evolve with sustained self-organizing processes in pursuit of promising questions for collective knowledge advancement (Tao & Zhang 2018), and advance their state of knowledge in ways akin to work of scientists (Chen & Hong 2016; Hakkarainen 2003). In the process, they learn basic content and skills, as they are continually engaged in reading, writing, finding new information, experimenting, revising ideas to address challenges raise by peers, raise new issues of understanding, and more generally, working intensively with ideas in a multimedia environment. With shared responsibility to advance conceptual knowledge, students are pulling in the same direction as the teacher.

Developing 21st-century educational competence

Misalignments also exist between 21st-century education competencies (Trilling & Fadel 2009) and pedagogy and practices as commonly enacted in schools. Creative ICT frameworks have been advocated to foster 21st-century competencies (Voogt & Pareja Roblin 2012). In contrast, current practices often focus on discrete skills taught as add-ons to the curriculum, failing to examine 21st-century competencies grounded in authentic and complex tasks (Voogt & Pareja Roblin 2012) and linking them to teaching models for creative work. The bifurcation of knowledge and skills create hurdles for harnessing the pivotal role of knowledge in deep learning.

In an extensive review of assessment for 21st-century education models, Scardamalia, Bransford, Kozma, & Quellmalz (2012) argued that 21st-century competencies need to be fostered in rich learning environments that reflect the actual characteristics of knowledge-creating organizations. Defining and operationalizing 21st-century skills one-by-one, while important for measurement purposes, may not be the best approach for designing educational activities. Put differently, an emerging approach of immersing students in authentic, complex knowledge-building environments is needed. Rather than simply working towards pre-determined skills, students develop creative capacity in emergent ways, going beyond 21st-century competencies to transliteracy, creative work with ideas and rotating leadership (Ma, Matsuzawa, & Scardamalia 2016).

Scardamalia and colleagues (2012) further proposed a unifying lens of 21st-century competencies through the Knowledge Building model. By elaborating how 21st-century education competencies are manifested in knowledge-creating organizations, they developed a framework for evaluating the extent to which technology-enhanced environments develop 21st-century

competencies for knowledge creation (https://cutt.ly/Iw7WDSj). Yang and colleague's (2019) analysis of Knowledge Forum® discourse provides evidence for higher-order competencies including metacognition, collaborative inquiry and sophisticated epistemic dispositions in an enriched Knowledge Building environment. In Knowledge-Building environments, basic and advanced skills are part of the same fabric, as the forms of discourse that foster basic literacy and numeracy enable competencies to develop in tandem with creative knowledge work. Educators may consider shifting from skills perspectives to assessing and developing 21st-century educational competencies in rich technology-enhanced environments for emerging alignments.

Equity and education for all

Another common belief holds that higher-order thinking and complex competencies are more suitable for high-achieving students. However, the design elements of the learning environment are critical – empirical studies have shown that with appropriate designs (Zohar & Dori 2003) and technological supports (White & Fredericksen 1998), low-achievers can also benefit through engagement in higher-order thinking.

The Knowledge Building principle "democratizing knowledge" (Scardamalia 2002) underscores the notion that every student is a legitimate contributor to community knowledge. Low achievers are not kept in the vicious cycle of working on basic knowledge, with knowledge creation work reserved for the capable student. Instead, in a Knowledge Building classroom, all ideas are valued and play a role in advancing community goals – students take collective responsibility to help one another succeed. Thus rather than the teacher as the person solely responsible, knowledge building communities are favorable to low

achieving students as the emphasis is on improving ideas and peers are helping by asking questions, explaining, providing additional material, and sharing responsibility.

Classroom studies provide evidence that students with low achievement scores can engage successfully in Knowledge Building. Moss and Beatty's (2010) work in three Canadian classrooms demonstrates that when students worked collaboratively on Knowledge Forum to solve algebra problems, both high- and low-achieving students benefited from using their peers' models to support their understanding. Knowledge Forum analytics illuminate individual differences in interaction dynamics –students who may be too shy to speak up during face-to-face discussions can find productive ways to contribute ideas online for others to build on. In a two-year study, Niu and van Aalst (2009) examined knowledge-building discourse among honor and basic degree students. Analysis of Knowledge Forum notes indicated that the writing of both groups reflected similar characteristics of Knowledge Building principles. In Singapore, So and colleagues' (2010) analyses of three primary science classrooms from low socio-economic backgrounds reinforce that both high- and low-achieving students benefit from Knowledge Building, with both groups showing gains on achievement tests. Research shows that low-achievers in a Visual Arts classroom in Hong Kong engaged in Knowledge Building discourse on Knowledge Forum in ways that are comparable to the regular cohorts in published studies (Yang, van Aalst, & Chan 2019). Knowledge creation is for everyone – all students can contribute to and improve ideas while achieving curricular objectives. Teachers need to consider students of diverse backgrounds in pedagogical and technology innovation for equity and access to knowledge creation.

Pedagogy and technology integration

Despite continued attempts to integrate pedagogy and technology into classrooms, classroom designs and enacted practices are often misaligned with the purpose of educating students for knowledge work. Misalignments exist as creative knowledge work requires open-ended inquiry, but many classroom designs focus on teacher-directed inquiry, scripted activities, initiate-response-evaluate discourse patterns, fixed groups and role membership, which lack emergence, integration and adaptive design. More expansive technology and generative designs are needed for emergence for knowledge creation. There is also a pervasive misunderstanding that ICTs are the panaceas for educational change. Yet these tools are too often used in generic ways, and compartmentalized outside the curriculum and teacher professional development, disconnected with other parts of classroom change. Even in classrooms involving extended work with innovative technology, there is a tendency to focus on individual or small group processes, rather than working as a collective to build community knowledge, with classroom work extensible to communities beyond the classroom.

Knowledge Building engages students in knowledge creation as in innovative communities, with students setting forth questions and initial theories and improving them as they gain new information and work to generate coherent explanations. Knowledge Forum technology is designed to make these complex processes transparent and accessible to students of all ages. Knowledge creation practices in classrooms require seamless integration of technology to bridge online and offline interactions, as well as to connect student ideas to the world outside of classrooms. Therefore, technology cannot be treated as a generic and add-on tool, but must be closely integrated with curriculum design, pedagogical intentions and knowledge creation goals. The Knowledge Building approach

focuses on evolving ideas along with an emergent curriculum supported by specialized features of Knowledge Forum technology to engage students in sustained creative work with ideas.

Whereas many technology-enhanced learning environments focus on knowledge construction, networking, and communication, Knowledge Forum technology is developed to embed knowledge creation in the production and refinement of ideas through creative knowledge work. Pedagogy and technology are integrated into classroom activity systems premised on a set of Knowledge Building principles with tightly coupled socio-cognitive and technological dynamics (Scardamalia 2002). In Knowledge Building classrooms, the teacher engages students in collaborative design using an emergent, progressive curriculum (Caswell & Bielaczyc 2001) and opportunistic groupings to advance collective understanding (Zhang et al. 2009). By departing from an emphasis on scripted procedures and tools, principles-based pedagogy and technology create conditions that enable students to work with the emergence of new ideas. Teachers and students co-construct the flow of inquiry as it unfolds (Zhang et al. 2007). Alignments for educational innovation need to be guided by principles working in classroom systems in emergent ways rather than using add-on pedagogy and technology tools. In short, the integration of theory, practice, and technology is critical in technology-based learning environments for the Knowledge Age.

Assessment, learning and collaboration

Another major area of misalignment in education for knowledge creation pertains to separation in assessment, learning and collaboration. With educational reforms, collaborative learning activities using technology in classrooms are commonly

conducted, and yet they are often disconnected from the assessment that continues to emphasize individual-based achievement, hampered by the institutional constraints and demands of testing.

A key Knowledge Building principle is "embedded, concurrent, and transformative assessment" supported by a suite of continually evolving Knowledge Forum analytics tools (Chen et al., 2015; and see next section). Assessment is 'concurrent' in that it provides instantaneous feedback, it is 'embedded' into the pedagogy, and it 'transforms' collective learning as assessment takes place (Scardamalia 2002). Pedagogical and technological designs are developed to address the disjoint, with students reflecting on their Knowledge Forum discourse - they monitor and assess their progress and identify what further work is needed. An empirical study by van Aalst and Chan (2007) shows students designing e-portfolios using Knowledge Forum reference notes and a set of four Knowledge Building principles as the criteria to assess their collective advance. Lei and Chan (2018) further examined the dynamics of reflective portfolio assessments for aligning learning, collaboration and assessment among university students in China.

More recent work includes the development and refinement of Knowledge Building analytics for illuminating and scaffolding collaboration by recording students' online activities such as contribution, interactivity, social networking, scaffold distribution, and lexical analysis for vocabulary growth (see Figure 1). Teachers and students can monitor their work and assess collective progress using these tools. Resendes et al. (2015) explored how comparative word clouds can be used by Grade Two students to support self- and collective reflections toward a more discursively connected community. Yang et al. (2019) used Knowledge Connection Analyzer to help students reflect on their Knowledge Forum discourse

for continuing work in their knowledge building journey. Different analytic tools embedded in Knowledge Forum are developed by the international community to make knowledge-creation dynamics more transparent for students and teachers and enable them to make just-in-time, data-informed decisions during their knowledge work. Alignments of collective and individual assessments for education innovation and creative knowledge work are needed, with an emphasis on formative feedback and collaborative design using technology.

Teacher professional development

The professional learning of teachers is often associated with formal courses, conducted by experts or academics that are misaligned with the needs of teacher learning in a knowledge society. There have been major research advances in teacher professional development in the past two decades, focusing on collaborative engagement in teacher communities that have led to the improvement of teacher knowledge and practices (Borko, Jacobs, & Koellner 2010; Fishman & Davis 2006; Prestridge & Main 2018; Voogt et al. 2015).

Knowledge Building teacher professional development is closely intertwined with student learning – the approach involves knowledge-creation at all levels. Chan (2011) discussed changes across different levels, macro-, meso- and micro-levels with teachers working as Knowledge Builders, and integrating different aspects of principles, designs and practice. In Tan and colleagues' (2016) dual-layer approach to Knowledge Building, teachers inquired about how to support students' collaborative idea improvement and created knowledge about Knowledge Building practices (i.e., they were Knowledge Building about their student's Knowledge Building). Teo (2014) studied teacher professional development using a problem-space model to examine perceived tensions

between curriculum/standards, technology, social interaction, and classroom structures and conceptual shifts that resulted as teachers became more proficient in Knowledge Building. Laferrière and colleagues (Laferrière 2018; Laferrière, Hamel, & Allaire 2013) incorporated Knowledge Building into the professional development of pre-service teachers that fostered teacher mentorship and collaboration during practicums in schools.

Similar to students' Knowledge Building, teacher learning mirrors these Knowledge Building and creative processes, and they work as knowledge builders alongside students and other stakeholders in the system to achieve collective goals. Teachers use the Knowledge Building principles of working with authentic problems, embracing idea diversity, and collective agency as part of a larger effort to advance knowledge of classroom practices. Students' ideas serve as material resources and common referents for teachers' discussions. Recent work has examined symmetrical advances in teacher communities when teachers work collectively toward progressive improvement of pedagogical designs and use Knowledge Forum analytics to deepen their classroom practices (Tan, Chue, and Teo 2016). Since educational innovation requires changes in teachers' epistemological and pedagogical beliefs, as well as their technological competencies, a community approach emphasizing teachers as knowledge builders would be more likely to bring about teacher change for collective knowledge advancement.

Student learning outcomes

Pedagogical and technological innovation are often misaligned with the schools' emphasis on individual academic achievement and, correspondingly, tensions arise between collective and individual learning and knowledge creation. A key

question pertains to issues and evidence of educational effectiveness and impact on student achievement using new approaches. Teachers often resist engaging in innovation because many hold the beliefs that these innovations would take up their regular teaching time and would not be beneficial to students' academic achievements.

The Knowledge Building model postulates that the focus on collective responsibility for knowledge advances drives learning as well as knowledge creation (Scardamalia & Bereiter 2014). From its first implementation in a school setting in Toronto and later extended to school systems in different countries, evaluation studies on students' learning have been conducted using design-based and experimental studies, sometimes including standardized tests and examinations. While there may be concerns with the tensions of higher-order thinking and basic skills, evaluation results have shown students perform better than comparison students on academic and standardized tests (Scardamalia et al. 1992; Hong et al. 2020; Wagner, 2020). Over time, the influence of Knowledge Building and Knowledge Forum technology on learning effectiveness has been examined in diverse curricular areas (CJLT special issue 2010), including primary science (Zhang et al. 2007); literacy (Zhang & Sun 2011), mathematics (Moss & Beatty 2010); history (Chan, Teo, & Lee 2016), geography (Lee, Chan & van Aalst 2006) and chemistry (Chan, Lam & Leung 2012). Most studies use some form of assessment for conceptual understanding and domain knowledge, and some examination results (Chan et al. 2012).

These studies show that while Knowledge Building focuses on collective knowledge work, there are positive learning outcomes at the individual level including basic skills, conceptual knowledge and examination results. Despite these advances, Knowledge Building faces challenges with prevalent beliefs in

schooling misaligned with knowledge creation. More systematic investigations are needed to connect collective advance and individual gains for the strategic alignment of research and practice. Innovations need to be perceived by stakeholders, including teachers, principals, policymakers, and parents, as advancing not simply students' creative competencies but also learning effectiveness and socio-emotional well-being.

A holistic approach to addressing multiple misalignments

Innovation is by nature disruptive and that changes at one level create changes at other levels, sometimes bringing more misalignments, thus a piecemeal approach to educational change would face difficulties. Knowledge Building is a progressive model that tackles multiple misalignments and continual change. In this paper, we examine misalignments and realignment efforts both in different areas and also across different sectors and levels to support synergistic change within and across school systems. Following the discussion on specific areas of challenges, we discuss research examples of theory-practice-policy synergy to illustrate a holistic and progressive approach to innovation across classrooms and schools systems. Three major areas are examined: (1) Engagement of multiple stakeholders as knowledge creators in multi-level networks and partnerships; (2) Continuous development of Knowledge Forum technology and teachers as co-designers; (3) Designing local and international networked Knowledge Building communities for innovation.

Engaging multiple stakeholders across school systems at multiple levels as knowledge creators

The Knowledge Building model highlights the importance of expanding the participation of educational stakeholders to enrich knowledge creation for new alignments. Toward this end, school-university-government partnership (Laferrière et al. 2010; Chan 2011) and multi-level networks (e.g., Teo 2019; Ma & Scardamalia in press) have emerged that support capacity building across stakeholders and systems, and for spreading knowledge-building innovations within the system. Specifically, the SUNG model (Laferrière et al. 2010), depicted in Fig 3, shows research-practice partnerships to create new alignments for knowledge creation in educational systems. While the school-university-government partnership is now more common, the SUNG model is premised on integrating theory-pedagogy-technology of the Knowledge Building model, and engaging stakeholders throughout the system as knowledge builders, building knowledge about knowledge creation.

Similar to the design-based implementation research (DBIR) (Penuel & Martin 2015) approach, the SUNG model focuses on design research that aims to create an impact in education systems at different levels with teams comprising educational researchers and practitioners. Several principles are emphasized: (a) focus on authentic practice problems, (b) integrating perspectives of multiple stakeholders, (c) commitment to iterative collaborative design, (d) systematic inquiry for research advances, (e) capacity-building for sustainable improvement in the systems, and (f) knowledge creation both for theory and improved classroom practices.

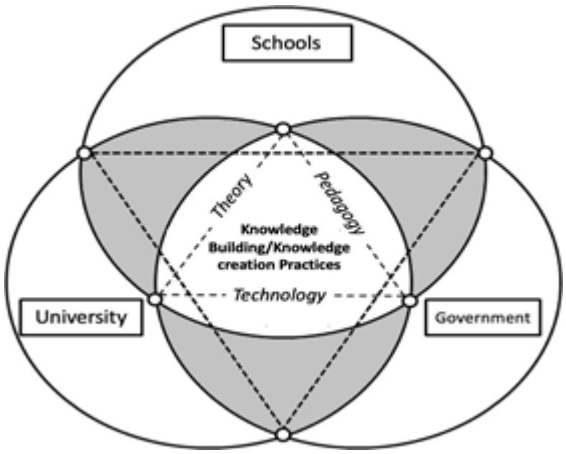

Fig 3. A tripartite model of school-university-government (SUNG), from Chan et al. (2020)

The SUNG model can be traced to research on the TeleLearning Network of Centres of Excellence (Harasim & Calvert 2002), where researchers and educators from institutions across Canada worked on iterative design experiments to develop innovative technology-supported approaches for schooling and including teacher professional development. The SUNG model has been used to support the development of Knowledge Building in different school systems bridging research and practice, including (a) Quebec schools through the Remote Networked Schools initiative, in partnership with the Quebec Ministry of Education and Laval University (Turcotte, Laferrière, Hamel, & Breuleux 2010); (b) Barcelona schools through the COMconèixer project, in partnership with the Department of Education and the University of Barcelona (Montane 2006); and (c) Ontario schools through the Leading Student Achievement initiative, in partnership with the Ontario Ministry of Education and the University of Toronto (Ma & Scardamalia in press).

In the Knowledge Building communities, different stakeholders work together, taking collective responsibility for engaging in Knowledge Building practice. Different sources of misalignments (Fig 2) can be tackled across different levels of the school systems when stakeholders work together.

Policymakers create alignment between Knowledge Building and other educational initiatives, such as 21st-century competencies and workplace skills development. Administrators create a failure-safe culture in their schools to encourage teachers to experiment with their practices using principle-based pedagogical and technological innovation. Teachers work with students and engineers to design socio-technical systems that generate novel and meaningful ways for students to self-organize around idea improvement, and researchers work with teachers to document the iterative design process and identify powerful practices that link to student outcomes. Learning and continuous development take place at all levels of the system, as researchers, educators, policymakers, teachers, and students become creators of new knowledge.

Continuous development of supportive technologies by multiple stakeholders

Knowledge Forum technology is central to Knowledge Building and integral to theory, pedagogy and school implementation at different levels. Development of Knowledge Forum technology plays an important role in addressing alignments across different levels and provides an example of creative knowledge work.

CSILE was the first online networked environment prototyped in 1983 (Scardamalia 2004). Development of CSILE was coupled closely with classroom implementation, suggesting early *alignment* efforts of technology-pedagogy integration in classrooms. More than a decade later, Knowledge Forum was developed to take advantage of the World Wide Web and to link databases across servers through wireless access to the Internet from classrooms. Multidisciplinary teams of teachers, students, researchers, and engineers engage in design-based research in classrooms to embed and refine new technologies into pedagogy. The evolving design of technology is based on classroom experimentations. As

Knowledge Building practices are examined continually, so is the development of Knowledge Forum. In 2020, the sixth generation of Knowledge Forum became available and the development work continues with different stakeholders to improve Knowledge Building pedagogy, assessment, and technology, reflecting the tight coupling among research and practice to support emerging alignments and sustained innovation in school systems.

More recent developments in Knowledge Forum® technology involve major efforts and developments in analytics tools– in line with big data and learning analytics research. New technology developments also arise from emerging needs for alignments among collaboration, learning and assessment (see the preceding section). Research has shown the promise of analytic tools for technology and pedagogical advances. For example, Zhang and colleagues (2018) developed the Idea Thread Mapper to help students identify inquiry threads that support their Knowledge Building journey. Chen and colleagues (2015) designed the Promising Idea tool to evaluate promising ideas and use them to sustain idea development. To explore the development and coherence of community knowledge, Knowledge Building Discourse eXplorer, or KBDex© (Oshima, Oshima & Matsuzawa 2012) was developed to incorporate socio-semantic network analysis. Lexical tools, such as word clouds help students find big ideas in their community knowledge (Resendes et al. 2015). These analytic tools are not only used by the researchers or teachers, but are also used by students for advancing their knowledge work (Yang et al. 2019), keeping in tandem the principle of epistemic agency with technology development.

The development of Knowledge Forum® technology takes a holistic approach to addressing interrelated elements for realignment: the epistemological view that knowledge can be continuously improved using visualization and

analytics to aid reflection; supporting the development of 21st- century competencies such as collective inquiry and rise-above; encouraging democratic participation in knowledge creation by creating access and opportunities for students from all backgrounds and abilities. The teacher communities not only learn about how to use Knowledge Forum, but they also use the technology as knowledge builders contributing to the teacher community, and incorporating analytics tools to advance their learning, professional interests, and proficiency with technology (Ma & Scardamalia in press).

From locally networked communities to international innovation networks

Another major approach to developing educational innovation is the creation of an international community of Knowledge Building. Although different historical and cultural contexts call for different practices, education for innovation implies common goals and transferable principles. Knowledge Building is implemented in classrooms, schools, and school systems in different countries; these locally and internationally networked communities, in turn, provide socio-cultural-technological infrastructures that can support new emerging alignments for schooling and educational improvements.

Knowledge Building International (KBI, http://ikit.org/kbi/) includes a global network of researchers, teachers, school leaders, policymakers and engineers working together and meeting regularly in Summer Institutes and other virtual events to advance knowledge about Knowledge Building. The participation patterns and dynamics of how members work towards developing into a dynamic, sustained network for building knowledge has been examined (Hong, Scardamalia & Zhang 2010).

As an example, the Knowledge Building Summer Institute provides opportunities for teachers from different countries to engage in collaborative design to advance their collective understanding of the Knowledge Building principles. Teacher learning is connected to international design experiments with students from different countries working on Knowledge Building including writing on Knowledge Forum® and using the analytic tools to support discussion around pressing global issues. Educators, researchers and other international members contribute to the collective goal of deepening Knowledge Building practices supported by technology. Stakeholders including policymakers, principals, teachers, researchers working on different design challenges at various levels of school systems have opportunities to meet and discuss gaps, tensions, and possibilities for developing new alignments for schooling in the Knowledge Age. Open innovation networks enable cross-fertilization of ideas and cross-diffusion of innovative practices (Chesborough et al. 2006) that may increase possibilities of developing alignments for schooling

Continuing work is taking place on the development of the Knowledge Building Collaboratory, to create a central design space for teachers design artefacts and optimizing affordances for open collaboration and experimentation through cross-fertilization of ideas and cross-diffusion of innovative practices (Ma & Scardamalia in press). The international community of Knowledge Building educators, researchers, and engineers are collaborating in virtual design sessions to generate solutions to complex issues at the intersection of theory, pedagogy, and technology while advancing socio-technical infrastructures and designs for Knowledge Building. Multinational and multi-level networks help advance educational innovations in Knowledge Building to maximize impacts on design, practice and policy impact.

Implications for policy and practice and future research

Misalignments are highly complex as they occur at different levels. Educational efforts to bring improvements through incorporating more technology, pedagogy and reform policies risk introducing more misalignments and disruptions. Engeström (2001) argued that changes bring about tensions and contradictions to a system, which could drive the creation of new knowledge, but these contradictions could also create new misalignments. Unless we have a self-sustaining and self- improving system, we will be enmeshed in the unproductive game catching up with realignments all the time.

Using the Knowledge Building model supported by research evidence from different countries, we have examined both the different sources of misalignments and alignment efforts as well as a synergistic and participatory approach with members taking collective responsibility in networks of Knowledge-Building communities. By focusing on a holistic approach and progressive improvement at all levels – classroom, schools, school systems and international networks – the Knowledge Building model provides a possible approach to addressing the prevalent and changing problems of misalignments in the Knowledge Age.

Implications for Policy and Practice

The contribution of this paper has been to highlight core issues, questions, and possibilities which may open up a discussion on a Knowledge-Building approach to educational re-alignment and school transformation. The preceding two sections examined different areas but they both emphasize the significance of *community and progressive improvement* central to Knowledge Building. This paper posits that when addressing misalignments in school systems for knowledge

creation, creating communities for collaboration and partnership, informed by the Knowledge Building model, would have useful implications for research and practice synergy. In particular, tackling pervasive and interacting misalignments may benefit from a more participatory and synergistic Knowledge Building approach toward symmetric knowledge advancement. While universities, government, and schools are often seen as distinct groups with misaligned interests, informed by the Knowledge Building and SUNG models, different stakeholders, teachers, policymakers, researchers can intersect in different ways building knowledge about policy and practice.

A Knowledge Building community approach supports sustained discourse, and technology would play a key role in transformative discourse among different stakeholders in a constellation of communities. Partnership, collaboration and coordination are needed at different levels –macro-level policy, meso-level enabling structures such as teacher communities and micro-level classroom enactment – a community of communities locally and internationally can be supported via technology, providing new insights and means for productive change. The Knowledge Building model with supportive technology would provide a possible framework with rich exemplars but continuing design work is needed to explore work in different communities and school systems.

Another major implication for policy and practice focuses on progressive improvement in self-organizing systems. We have argued that misalignments are difficult to tackle as changes within systems often bring additional misalignments. Knowledge Building focuses on progressive change through collective, interconnected efforts and design-based research considering changing practices within changing contexts. To minimize unintended disruptions with innovations, self-organizing and self-improvement systems would be needed. As shown in our

examples, these self-organizing systems would have the following characteristics: (a) innovation emerges through continuous iterative improvement, (b) self-improving innovation hubs working at different levels, (c) distributed expertise and roles of stakeholders are leveraged (e.g., policymakers and educators), (d) different epistemological perspectives, culture and processes of innovative practices are integrated (e.g., between engineers, educators, data scientists), (e) multiple roles played by participants (e.g., a researcher who contributes to policymaking, a student who contributes to designing of the technological platform). These characteristics may help provide pointers for policymakers, researchers and educators for developing self-organizing systems for addressing continual changes.

Implications for Research and Future Directions

We have discussed examples of successful models of large school systems showing research-practice-policy synergy, but there are also significant challenges requiring further work in research and design. Specifically, the emergent dynamics, complex, and enabling conditions of these progressive self-organizing systems are not well known and need to be investigated further. How do these successful models of scaling emerge, and how can collective knowledge and practices be developed and diffused to different communities? The creation of new ideas and innovations is key in these communities, however, developing collective agency for self-organization and emergent processes remain challenging.

Second, Knowledge Building model emphasizes the roles of technology and highlights assessment tools that both examine and scaffold collaboration. There are continuing efforts on examining the use of learning analytics in

Knowledge-Building classrooms, but how analytics can be used to support symmetrical advances for multiple players and stakeholders across a global network of knowledge building communities requires longitudinal investigation and continual innovation of the very practices and technologies that sustain the network.

Third, large international design experiments are currently underway involving teachers and students and practitioners across multiple communities around the world; the designs and dynamics are new and need further exploration including roles of stakeholders and boundary-crossing in these communities. There are challenges in studying these complex networks of networks, such as co-existence of competition and collaboration and fissures between boundaries at different levels, yet these areas offer promising new directions for innovation in education.

Conclusions

The notion of community and mobilization of researchers and educational stakeholders across the globe for shared goals is observed in multiple communities. Since 2009, the EduSummIT organization has involved policymakers, researchers and educators to discuss problems related to the use of technologies in the education for educational impact (Lai et al. 2016). The recommendations from EduSummIT are disseminated to UNESCO to create an impact on education systems around the world, with the goal of strengthening ties between research, policy, and practice. The Knowledge Building model discussed in this paper has its distinctive theoretical framework, principles and examples for knowledge creation, but there are general implications for knowledge communities. While different research groups may focus on different issues of

misalignments, and some developing towards international networks and knowledge communities, it is our hope that the Knowledge Building model, as one of the well-established examples, may contribute to the ongoing discussions to create a meaningful and long-term impact on pedagogical and technological innovation in education.

This paper has examined the problem of creating new alignments in the Knowledge Age focusing on knowledge creation in education using the Knowledge Building model. We emphasize engaging students directly in creative knowledge work as they enact sustained inquiry and collective responsibility supported by technology. We identify misalignment issues in different areas and multiple levels and sectors and discuss how they can be addressed through Knowledge Building practice and networks. It is important to design, implement, and research self-sustaining and self- improving practices at different levels. Progressive improvement and collective responsibility are important principles for classrooms, schools, school systems and international networks. Continual design efforts integrating theory practice and policy are needed for progressive improvement and emerging realignments of school policy, practice, and research.

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