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Infrastructuring for Knowledge Building

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Abstract: This symposium brings together scholars from the international Knowledge Building community to advance an emerging line of research that aims to strengthen infrastructures for Knowledge Building and tell the "untold stories" of infrastructuring activities that are key for implementing and sustaining Knowledge Building in various contexts. Infrastructuring as a practice in design-based research (Penuel, 2019) moves away from static views of infrastructure and acknowledges the hidden processes of (re)designing infrastructures. For innovations like Knowledge Building, illuminating the process of infrastructuring would shift the focus from learning outcomes, pedagogical strategies, and technological designs to include the larger system that constrains and gives meaning to these components of work and to yet-to-be developed systems to advance knowledge for public good.

Introduction

Knowledge Building (KB) is an ambitious educational innovation that is heralded as the most long-standing design experiment in the learning sciences. While KB shares key theoretical tenets with other constructivist learning approaches, KB has its own unique historical roots and philosophical orientations (Scardamalia & Beretier, 2010). In a nutshell, KB is grounded in decades of research on creative expertise, an ontological treatment of ideas as artifacts independent of human minds, and a community approach to learning, cognition, and knowledge creation (see Chen & Hong, 2016 for a review). Grounded in these core tenets, KB moves beyond general ideas of constructivist learning to cultivate a culture of knowledge creation in classrooms, where every student is expected to have a way to contribute to knowledge-creating efforts (Chan & van Aalst, 2018; Scardamalia & Beretier, 2010). These core tenets shape KB's identity as an *idea-centered* approach (Hong & Sullivan, 2009), in contrast with task- or activity-centered approaches, and demand classroom practice that is more emergent, responsive to participants and not reducible to a set of predefined procedures. A set of design principles were derived to advance practices and designs so that they are more in keeping with how knowledge has been advanced historically and continues to be advanced globally (Scardamalia, 2002).

The theoretical ideas and principle-based practice of KB are often in tension with typical school practice. Such tensions are common for school reforms, which often need to cope with existing infrastructures that are either dysfunctional or counter-productive for the new practice (Fullan, 2001). KB is no exception in this regard. It proposes a view of education that challenges dominant models of contemporary schools in many ways. For

most members of society, knowledge production is rarely a mission of schools; teacher training opportunities gravitate towards mandated curricula or policies (e.g., new curriculum standards); subject areas often operate in silos so they are not organized for transdisciplinary inquiry; the pressure to cover the curriculum does not leave much room for students to explore ideas, especially in regimes where high-stake standardized tests prevail. This list can go on, all leading to an impression of KB being difficult to implement in a school. Indeed, to implement KB in a specific school environment is to be confronted by tensions with established infrastructures and requires careful design work that involves the transformation of these infrastructures. Despite many concerted efforts to scaffold the adoption of KB and demonstrations of student enjoyment and effectiveness in advancing community knowledge (e.g., Chen & Hong, 2016), questions persist, especially when scaling KB to large education systems.

Prior work on KB has documented success stories of sustaining KB, often based on school-university-government partnerships (Laferrière, et al., 2015; Zhang et al., 2011). Such partnerships create opportunities for design experiments, teacher learning, resource alignment, and systemic change. But without sustained collaborations enabled by these partnerships, core principles of KB are in danger of being subsumed by established practice and system inertia. Partners change with new governments; in one notable case, a top-level political shift essentially ended support of educational innovation, including halting what had been a very successful scaling up of Knowledge Building. While ongoing events and webinars offer ways to reach a broad international audience, how to sustain KB in large education systems remains an open question.

To tackle these challenges, the proposed symposium brings together scholars from the international KB community who are cultivating conditions for KB in different contexts. We have a shared interest in exploring how the notion of *infrastructure* (to be elaborated below) could offer a useful lens for examining and sustaining educational innovations like KB. Recognizing infrastructure as being embedded, transparent to use, and linked with conventions of practice (Star and Ruhleder, 1996) creates new angles for investigating challenges facing educational innovations. This symposium is grounded in sustained dialogues in the past two years, at two Knowledge Building Summer Institutes (KBSI) and an ISLS workshop. One important take-away from these events was that we need to intentionally surface processes of dealing with existing infrastructures as well as creating new ones when implementing KB. The proposed symposium is an important step towards that goal by including a set of presentations telling the "untold stories" about infrastructuring in KB contexts.

Below, we first present a brief review of the infrastructure literature, as well as infrastructuring as a practice for building equitable and sustainable innovations in education (Penuel, 2019). We then present a set of summaries about infrastructuring in KB. The presented analyses are retrospective and reflective. By conducting these analyses, we attempt to reveal productive practices, processes, or working models of KB infrastructuring as well as challenging issues/tensions that we need to investigate. By looking across sites, the symposium motivates a series of ethnographic studies of KB infrastructures that surface infrastructuring activities, as well as new efforts to transform education infrastructures for KB and other ambitious initiatives in the learning sciences.

Infrastructures for Knowledge Building

Infrastructure has gone through intense theorization and empirical investigation in disciplines such as Design, Information Science, Human-Computer Interaction, and the Science and Technology Studies, leading to a rich body of literature reflecting diverse perspectives. While the traditional sense of infrastructure (as noun) is commonly depicted as a substrate (e.g., roads and wires) on which something else runs or operates, seminal work by Star and Ruhleder (1996) argues that infrastructure is *relational* to the users; a thing can be considered infrastructure only when it serves an infrastructural function for someone (Read, 2019). This relational perspective broadens the focus from the technological product and brings the user's perspective into the picture. The implications are profound, stretching the scope of design from the product to activities that leverage the product and shifting the power from professional designers to users who carry on these activities.

Building on this idea, Karasti & Syrjänen (2004) coined the term *infrastructuring* to recognize the ongoing process of design and redesign when an infrastructure is created in a setting. In healthcare, for example, infrastructuring entails clinicians, medical records, and practices becoming parts of socio-technical networks with longer reaches and more channels, with sophisticated coordination happening among these distributed actors. As such, infrastructuring emphasizes the processual, ongoing nature of design and draws attention to the extended periods during which infrastructuring unfolds. Infrastructuring also blurs the boundary between users and designers, recognizing important design efforts by users when a product is put into use (Pipek & Wulf, 2009).

These notions of infrastructure are yet to be widely recognized in the learning sciences. According to Penuel (2019), infrastructures in education systems include "standards for student learning; curriculum materials; student assessments; teacher professional development; instructional techniques and routines; policies; school schedules; organizational routines, such as grade-level meetings; and personnel evaluation systems" (pp. 662-663). These things are coordinated to give rise to a working infrastructure for teaching and learning. As learning

scientists, we are engaged in infrastructure redesign—intentionally or not—when conducting design experiments or solving practical problems with school partners. Such work is infrastructuring (Karasti & Syrjänen, 2004). A significant gap in the learning sciences literature is that such infrastructuring work is rarely captured. There are informative discussions of technological, social, and organizational infrastructures (Bielaczyc, 2006; Bolmsten & Manuel, 2020), but we still lack studies into the nuanced processes of infrastructuring. For innovations like KB, telling the "untold stories" of infrastructuring would broaden the focus from learning outcomes, pedagogical strategies, and technological innovations to include the larger system that constrains and gives meaning to these things.

In this symposium, we define infrastructuring as "activities that aim to redesign components, relations, and routines" that influence the ability of and the ways in which school or classroom communities engage in knowledge building (adapted from Penuel, 2019, p. 659). Following this definition, each presentation in the symposium attempts to respond to either or both of the following questions:

1. What essential infrastructures are needed to support and sustain KB?
2. What infrastructuring work is conducted, with whom, to support and sustain KB?

Collectively, the symposium aims to surface stories that need to be told from efforts of implementing and sustaining KB so that we can further discuss pertinent infrastructures for KB and strategies of changing existing infrastructures when implementing KB.

Knowledge Building and the infrastructure of unquestioned practices and beliefs

Marlene Scardamalia & Carl Bereiter

The knowledge building story is in many ways a story of innovating school infrastructure. Schools were built for individual achievement, to transmit established knowledge, and develop academic skills. Knowledge Building focuses on collective responsibility for advancing public community knowledge and engaging students directly in the means by which knowledge in the world is advanced.Moreover, it goes beyond treating knowledge as something intrinsically valuable to treating it as a vital contribution to individual, community, and society wellbeing. School systems and first-level post-secondary institutions were not designed for knowledge creation and in fact have certain features of their infrastructures that militate against it. The kinds of questions and concerns raised with respect to Knowledge Building reflect beliefs and practices so firmly established that they are viewed as hardwired as opposed to adaptations to current infrastructure. The following are three beliefs so deeply entrenched that they are often treated as self-evident but that are directly challenged by Knowledge Building:

1. *"Best practice" consists of procedures.* The need for procedures and finding a niche within current practice is reflected in questions such as When should knowledge building be started? What is the best principle to start with? How much of the school day should be devoted to knowledge building? Infrastructure conducive to Knowledge Building would eliminate age and school-day boundaries for creative work with ideas. Principles would operate as design parameters for new systems of interaction--not considered one at a time, but as part of a complex, interactive system of real-time enhancement of creative knowledge work, with boundless opportunities for innovation.
2. *Official requirements take precedence over educational concerns such as depth of understanding and epistemic agency*. Requirements are reflected in questions such as How can I be sure test scores will improve and not get worse? How do I cover all the required topics and still have time for knowledge building? Knowledge Building does not ignore official requirements but rather engages students in goal setting. Students are not blind to official requirements; they take them into account as they take collective responsibility for emergent rather than fixed goals for advancing community knowledge, with possibility of exceeding rather than simply meeting requirements.
3. *Current structures provide necessary support for students*: Assertions such as "students are too young, unmotivated, lack background knowledge, not ready" are familiar accounts of student limitations, without consideration of infrastructure obscuring student potential.

Other features of infrastructure, such as physical and technological environment, are of course significant; but they tend to be shaped according to taken-for-granted practices and beliefs, which therefore warrant prior attention if infrastructure for Knowledge Building/knowledge creation is to be improved.

Knowledge Building sees environmental conditions and infrastructure as malleable and improvable. In this presentation, we convey four shifts represented by Knowledge Building and results accompanying each shift.

Curriculum shift: From meeting to exceeding curriculum expectations; from curriculum as a closed space for students to open spaces for collective responsibility. Results of engaging students directly with curriculum mandates and providing support for their ideas show student ideas run deeper than many think possible and lead to interdisciplinary perspectives; students find curriculum guidelines and expectations a good read and can identify student ideas not represented in guidelines as well as curricular issues they should pay more attention to.

Professional development shift: From implementation of best practices to continual innovation. Analysis of teacher discourse in face-to-face professional learning communities and online networks has shown limited use of discourse aimed at innovating practices. When design-mode discourse is embedded in environments, teacher discourse becomes more focused on design artifacts and iterations by which practices are innovated.

Assessment shift: From working backward from assessment goals to working forward to knowledge creation goals. Assessment benchmarks typically define goals, with curriculum and activities focused on meeting predefined benchmarks. Knowledge Building analytics allow assessment of work as it proceeds. Results suggest that knowledge builders do fine by traditional assessments, while being able to keep their ideas on trajectories to public knowledge.

Community shift: From communities with primary focus on socio-cognitive dynamics of active learning or primary focus on socio-emotional wellbeing, to communities belonging to a world community, with positive emotions such as joy and happiness coming from advancing knowledge for public good.

Restructure teacher planning and reflection to support student-driven Knowledge Building

Jianwei Zhang & Hyejin Park

KB theory and pedagogy aim to enculturate students in authentic knowledge creation practices. The classroom implementation of KB features an idea-centered classroom flow, which integrates flexible arrangements that support students' continual idea advancement as a community (Scardamalia, 2002). The classroom processes are co-improvised by the teacher with students following a principle-based approach (Zhang et al., 2011). How can such dynamic KB processes be incorporated in schools and sustained over time? The concept of "educational infrastructuring" provides a framework for investigating the challenge of implementation and sustainability. According to Penuel (2019), infrastructuring is about creating conditions that support educators in making innovations into "working infrastructures" for organizing learning activities. This study looks into ways to restructure a key component of teachers' practice: their ongoing classroom planning and reflection that are essential to teaching for student-driven KB.

Teacher lesson planning typically follows a prescriptive framework of instructional design that works from pre-defined learning goals to plan and sequence classroom activities and materials (Gagne et al., 2005). This approach is also used to design project-based learning that addresses pre-defined knowledge goals through carefully designed inquiry tasks and collaboration scripts (Kirschner & Erkens, 2013). Scaffolding student-driven KB and improvisational discourse requires the teacher to embrace more open-ended and emergent planning that responds to student-generated interests, questions, and ideas (Jacobs et al., 2010; Richardson, 2013; Zhang et al., 2011). Instead of directing students to work on teacher-designed tasks and move along a pre-defined path of inquiry, teachers in knowledge building communities co-construct inquiry directions and processes with students (Zhang et al., 2011, 2018).

As part of our multi-year design-based research to implement KB in science at a public elementary school, we worked with a team of teachers to restructure their lesson planning, reflection, and classroom practices. The goal was to support emergent planning for student-driven KB, leveraging resources and analytics for teacher noticing (Barnhart & van Es, 2015) guided by core KB principles (Scardamalia, 2002). Drawing upon the related literature (Jacobs et al., 2010), our design framework highlights three interconnected elements of reflective noticing and planning: Attending, Interpreting, and making pedagogical Moves (AIM) (Park & Zhang, 2022). Specifically, in a knowledge building community (classroom), the teacher needs to (a) attend to students' evolving ideas and inquiry practices to detect dynamic information about what is going on and what is new and emerging; (b) interpret the classroom information to understand how students are thinking now, in relation to their work in the past and potential idea development in the next phase as informed by the "big ideas" in the disciplinary areas and the teacher's prior classroom experience; and (c) in response to the evolving landscape of knowledge work, envision strategic pedagogical moves (choices) to further student thinking, inquiry and collaboration.

In each KB initiative co-facilitated by a team of teachers, each teacher kept a weekly reflection journal to record his/her classroom observations, thoughts, and responsive planning using a reflection template. The prompts in this template helped make the elements of A-I-M explicit for teacher reflection. On the top section of each week's journal was a list of the above-noted knowledge building principles. The space for teacher reflection

was organized as four columns: (a) The wondering (inquiry) area(s) in which the observed work took place; (b) what the teacher noticed ("I notice…"); (c) the teacher's interpretation and understanding ("I think…"); and (d) possible classroom moves ("In the following week(s)…"). Analytic tools were designed and used to trace students' ongoing KB processes and progress and provide feedback data that supported teacher noticing of emerging inquiry questions, knowledge advances, idea connections, and individual needs. The weekly reflection journals were shared within the team of teachers and researchers. Key points of noticing and reflection were brought to weekly/biweekly meetings during which the teachers reviewed student knowledge advances and problems in each classroom and discussed plans to further student KB.

We conducted a qualitative analysis of the teachers' journal entries in connection with rich classroom data. The analysis generated a detailed temporal view of the teacher's ongoing noticing, envisioning, and classroom actions, which responded to and further reshaped student-driven inquiry efforts. The findings shed light on ways to support teachers' emergent planning and responsive teaching practices that serve to enhance student epistemic agency for ever-deepening knowledge work. Teacher practices involve iterative cycles of teacher noticing, envisioning, and classroom actions that go hand in hand with student-driven efforts for continual idea advancement. The design framework, analytics, and resources developed to restructure routine practices of teacher lesson planning and reflection in our project may be adapted to leverage KB implementation and innovation at new school sites and support teacher professional development.

Infrastructuring for Knowledge Building design studios

Chew Lee Teo, Guangji Yuan, & Alwyn Vwen Yen Lee

Creating an authentic knowledge building inquiry environment requires a comprehensive understanding of the KB principles and the key components that construct it. One of the key elements of knowledge-building settings is shifting students from passive receivers to knowledge creators for individual and collective reflection efforts, where students can engage in the dynamic process as key stakeholders to co-construct the shared inquiry journey (Zhang et al, 2018). The main challenge is how group reflection externalizes the thinking process and creates a visual presentation of the synthesized big picture and sustains it over time (Yuan et al., 2022).

Study context: Over the last four years and continuously throughout the pandemic, we created an authentic inquiry environment outside of school, the student Knowledge Building Design Studio (sKBDS), where we can reduce the proximity between the themes, topics, and the student's ideas and discussion. There are intricate connections between the three concepts and our goal is to facilitate idea-centric discussions that require heightened awareness and consideration of the emergent structure of the students' thinking process made visible in the knowledge building environment via the use of the "Journey of Thinking" (JoT) as a group activity to capture metacognitive processes, support the active construction of the group's developing knowledge, and sustain their group focus over time (Yuan et al., 2022). JoTs are students' group notes consisting of sentence scaffolds such as "I used to think," "Now I understand," and "Our next question".

Orchestration graphs and impact: To support the JoT processes in the sKBDS, a unique aspect of infrastructuring in sKBDS involves integrating orchestration graphs to increase the visibility of infrastructures and understand how they are implemented. Orchestration graphs illustrate the key stakeholders, activities, and relationships between activities over time and across the multi-level spaces (individual, group, community) within the sKBDS. By taking a design-based approach, researchers initiate designs and receive feedback, reflect on the research gaps, and update the designs in the orchestration graphs.

Between iterations of the sKBDS over the four years, we unpacked the designs and dynamics with updates to designs that increased students' epistemic agency through emergence grouping and increased idea improvement through sustained metacognitive reflections. Our findings from mixed-methods studies focused on idea complexity and diversity, showing that students' participation is tied to the learning environment and infrastructure design. This novel design process and resulting findings within the KB environment provided insights that may guide other teachers' adoption of idea-centric learning to support students' sustained inquiry and collaborative knowledge building. Ultimately, the use of orchestration graphs has resulted in a rethink across different levels of learning and has had an impact on teaching practice.

In summary, sKBDS experienced drastic changes from fully face-to-face to fully online format, and will soon be conducted in a hybrid format in the coming iteration due to the pandemic constraints. Within those iterations, we tested the key components for infrastructuring for an authentic informal KB learning environment, including the stakeholders, relationship among stakeholders, design, KB culture, and integrations of orchestration tools. These iterations highlight the importance of being flexible in integrating key components to construct an authentic KB learning environment in different learning formats.

Reactive infrastructuring to sustain Knowledge Building innovations in the face of institutionally-led breakdowns

Yotam Hod, Shiri Kashi, & Etan Cohen

Infrastructuring for knowledge building entails a set of complex strategies and practices to successfully reach desired outcomes. Some of these – such as engaging in meta-design and continually evaluating infrastructures (Chen, 2022) – require *proactive* engagement. Other practices – such as dealing with breakdowns and subsequent coherence-building (Star & Ruhleder, 1996) – are more *reactive*. While in principle it is important to be both pro- and re-active, this research sheds light on the latter of the two. That is, our goal is to further explicate the way changes in broad infrastructures, often outside of local control, are negotiated and reacted to at more local levels. In the particular case that we use to instantiate our insights, we describe how top-down changes to university infrastructures required a team of faculty members who led a graduate program to react to an infrastructural breakdown and respond at the grain-size of a changed policy and a new communication channel to build a new coherence. This ultimately helped sustain the knowledge building innovation that was in place.

The setting of our case study was at the University of Haifa Educational Technologies graduate program, which has been running for nearly two decades and has a highly successful reputation across the country. The program is unique in that it provides a robust infrastructure to foster a humanistic knowledge building community, which attends both to the personal growth of its participants as well as continual, collective idea advancement (Hod & Ben-Zvi, 2018). Since the inception of the program, the infrastructure required to support the humanistic knowledge building culture has been a work in progress. A system of entangled components comprising the infrastructure supported the strong community cohesion that was felt in the program. These components included a new learning space and technological infrastructure that was customized for the needs of the community, a variety of cutting-edge approaches to knowledge building across courses, a sequence of courses that were interconnected and tailored to the larger knowledge building endeavor, and relatively small courses and time in the program that allowed for community-building that fostered close relationships among students and faculty.

A breakdown in this infrastructure occurred when an institutional directive was issued that effectively lowered the teaching load of faculty members by 25 percent and removed several adjunct lecturers to compensate financially for this change. The leader of this initiative argued that the number of students in courses that would be enlarged as a consequence would not damage the instructionist pedagogical approach that was prevalent. Despite some opposition, these changes were ultimately approved by the institution, causing a serious misalignment between the infrastructure that the University provided (number of courses and faculty members to support them) and the desired goals of the local, educational technologies program. In particular, the unique humanistic knowledge building pedagogies that were designed around the small and intimate courses were threatened by the large-scale infrastructural change.

In reaction to the newly imposed structures, the faculty of the program needed to make a number of innovations to build coherence between the broad infrastructure of the institution without compromising the local infrastructure. One key reaction that the faculty made to the program was policy-driven. Hitherto, the program required students to complete either 36 or 40 credit hours (depending on track) to graduate. Realizing that this was four more than the required national policy, the faculty made a policy change for the incoming and subsequent cohorts that reduced the requirements and ultimately the number of courses that the faculty needed to offer. A second, interrelated change involved coordinating with a neighboring program to share several courses, so that students maintained a healthy range of electives to choose from. This required changing the department-level infrastructure by establishing cross-program meetings (along with program coordinators) where schedules could be aligned and new systems could be developed to facilitate this implementation. Together, these two changes allowed the vital components of the existing humanistic knowledge building infrastructure to stay intact.

To sum up, infrastructuring entails being both pro- and re-active. Reactive infrastructuring may involve dealing with unexpected breakdowns that result from changes to larger levels of infrastructures that are insensitive to particular local needs. The grain-size of the resultant changes can be small and nuanced, such as adjusting policies or establishing new relationships that compensate for the breakdowns by re-aligning the existing, nested infrastructures. Likewise, as discussed by Penuel (2019) but expanded on here, infrastructures are deeply entangled in one another, such that a disruptive change in one can cause disequilibration that must be compensated for elsewhere in the infrastructural ecosystem.

Points of infrastructuring in design-based research on a first-year course

J. Oshima, R. Oshima, Kawakubo, Kayagi, Yamashita, Kumazawa, & Lu

The idea of infrastructuring discussed in the symposium brings a new insight into conjectures in design-based research (DBR) (Sandoval, 2014). In the infrastructuring studies, "infrastructure is only infrastructure when it serves an infrastructural function" (Read, 2019, p. 243). Therefore, through an iterative process of DBR over the years, design embodiments should be implemented not only to facilitate expected mediating processes but also to be infrastructured in a context. To re-think an iterative process of DBR from the infrastructuring perspective, we conducted a small ethnographical study of design conjectures by focusing on how various stakeholders structured our design embodiments under the breakdown of the installed base of extant infrastructure (Pipek & Wulf, 2009).

Study context: In the last ten years, we have conducted design-based research on a project-based learning course for first-year students in the undergraduate program in a software engineering department. Our instructional goal was to develop students' ability to participate in knowledge-building practices through designing a product. Over 70 students took a course in their second semester as a requirement for their program. In our design conjecture, we implemented (1) a generative task structure such as developing a product, (2) a knowledge-constructive jigsaw activity as a participation structure, and (3) Knowledge Forum as a CSCL system where students reported progress in their projects and individual reflections on the progress reports every week so that they could regulate their activities by monitoring own and others' progress in idea improvement (Splichal et al., 2018). The course was designed as a blended course where students came to face-to-face class activities every week and used Knowledge Forum as a space for them to communicate and reflect on their thoughts in between their class activities.

Narrative of a point of infrastructuring: In the past few years, we decided to change our instructional design significantly due to COVID-19. It became a "point of infrastructuring"—a moment when the infrastructure becomes visible and is intentionally worked on (Pipek & Wulf, 2009). The virus outbreak forced us to think of a new style for our course by surfacing several actors and factors of our infrastructuring. One such factor was the new regulation of conducting classes at our university. In 2020, we had to modify the communication infrastructure to entirely online from the original blended format. The factor disturbed the relation among our embodiments in the course design. When face-to-face interaction was unexpectedly replaced with synchronous but online interaction using ZOOM, the social presence for students to be in the class as a community and its connection to their own groups could not be perceived by them. Consequently, the breakdown resulted in the unsuccessful development of students' ability to participate in knowledge-building practices.

In 2021, though, we anticipated another point of infrastructuring. In Japan, the circumstance around COVID-19 was gradually relieved, and the course regulation at our university allowed us to ask students to come to their classroom if they intended. As a result, the course was designed in a hybrid communication format. Some students participated in their group activities using ZOOM with their intentions. The change in the regulation surfaced students as stakeholders to think of the course design. Their intentions were essential for us to decide on the format and modify the design during the course. In this presentation, we will talk about our experiences of how we (designers) collaborated with students (users) in infrastructuring to improve our course design.

Infrastructure to bridge classrooms with public discourse

Bodong Chen, David Groos, & Xinran Zhu

As a design principle of KB, *pervasive knowledge building* encourages a deeper connection between student learning and issues surrounding them, in both physical environments and web spaces. Considerations of learning ecologies recognize both relational and material resources essential for supporting learning across space and time. Supporting learners to move across different spaces requires considerations of infrastructures that are at play in their learning ecology. Infrastructural work is needed to recognize dynamics in the ecology and to (re)configure conditions for knowledge building. In this presentation, we share moments of infrastructuring in a design research project named IdeaMagnets that was situated in a long-term research-practice partnership.

The IdeaMagnets project's primary focus was to build a technological infrastructure to bridge Knowledge Forum (KF) and public discourse on the web. Through design workshops participated by science teachers, a technological design was created to bridge Hypothes.is—an open-source web annotation tool—with KF so that students could easily capture ideas on the web and then import ideas into their KF discourse. With the developed technology, the research team co-designed a classroom intervention with a high school teacher and involved five science classes to build knowledge about energy and elements using KF and IdeaMagnets. Following guiding questions of this symposium, we retrospectively analyzed design documents and team communication data to surface infrastructural work during the classroom intervention phase of the project. We paid special attention to designers of emerging infrastructures, as well as how power structures were recognized and reconfigured during infrastructuring processes.

Several areas of infrastructural work were revealed from this analysis. First, in preparation for the classroom intervention, the teacher played an instrumental role in pedagogical design, bringing to bear his knowledge of the curricular topics, students, and school, as well as his understanding of progressive inquiry. The design work, participated by the teacher and two researchers, unfolded in a Google Drawing document. The final document included KB principles (e.g., beginning from student ideas), stages of the intervention that were mapped onto the school calendar, information and technologies resources in the classroom, and a portfolio-based assessment system. Important infrastructural work was taking place in the document, to align KB and the project's goals with curriculum objectives, school context, and assessment needs facing the teacher. This work, led by the teacher, was creative and consequential for student learning.

The second type of infrastructuring happened throughout the classroom intervention when the project team attempted to facilitate information flow across different digital spaces. While the project's primary focus was to bridge KF and public information sources, the teacher incorporated another CSCL technology named TalkWall in the early phase of idea generation and engaged students to select ideas from TalkWall to be further discussed in KF. Later when the class needed to search information about the Green New Deal, students realized they could not access certain websites not whitelisted by the school district. They circumvented the problem by turning off school WIFI on their devices. These two incidents of infrastructural work—one proactively creating cohesion among technologies and the other reactively coping with a breakdown—were not planned by the research team but created conditions for KB discourse in the classroom.

Finally, to meet the need for assessing student learning and participation, the teacher designed a portfolio-based assessment system that asked students to select and reflect on digital artifacts that could demonstrate their learning. To support teacher assessment, the researchers provided additional support, leading to the teacher's adaptive use of the KF search function when assessing student learning. This work was needed because the teacher and his instructional team were accountable to student progress. By involving students to curate and reflect on their contributions, the assessment system was also successful in retaining student agency. However, it was cumbersome due to the amount of manual work the teacher had to do, motivating further infrastructural work.

In summary, this analysis demonstrates the nuanced process of incorporating an innovation, the IdeaMagnets project, in a classroom setting and extensive infrastructural work to integrate the intervention in existing infrastructures. The teacher's creativity and resourcefulness were especially key, creating coherence between project goals and curricular objectives, bridging the project with existing infrastructures, and finding solutions to address infrastructural frictions. Following Chen (2022), future work would engage in meta-design, i.e., designing for design, so that infrastructural work surfaced by the analysis would be purposefully supported.

Multi-level infrastructuring for Knowledge Building innovation: Classroom, school and international teacher communities

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Despite advocacy for educational change, major misalignments continue to exist between schooling and innovative practice. For knowledge building/creation, common beliefs focus on schooling as preparing students for future rather than engaging them directly in knowledge work; and schools are viewed as innovation adopters not knowledge-creation organizations (Scardamalia & Bereiter, 2010). Different misalignments such as views about knowledge, tasks vs. ideas; individual vs. collective and best practice exist within and across multiple levels of schooling (Tan et al., 2020). Infrastructuring as progressive improvement not static conditions is needed (Karasti & Syrjanen, 2004; Penuel, 2019). This project examined knowledge-building innovation in a primary school in Shenzhen (China) with groups of teachers working in Science, Mathematics, Chinese and English classes over the past two years. We discuss infrastructuring at multiple levels including (a) classroom community, (b) school and teacher community, and (c) international teacher community/network.

Classroom Community. Class size in China normally has over 50 students, and infrastructuring needs to turn obstacles into opportunities realigning classroom practice anchored with principles. Across different classrooms, typically students initiate their inquiry using a community-view seeding diversity of ideas/questions; teacher-students co-develop 'juicy questions' (Zhang et al., 2018) for collective inquiry. These questions become emergent progressive curriculum; large class size enhances opportunistic groupings for idea emergence; with large number of notes, analytics tools including promising ideas and KBDex help students collectively reflect on their knowledge building trajectory. Infrastructuring for beliefs, practice, and technology use helps students develop new views of knowledge and identity for sustaining knowledge advances as a community (see social infrastructure, Bielaczyc, 2006). Analyses of Knowledge Forum (KF) writing indicate students developing increasingly cohesive knowledge building while improving on learning outcomes supported by classroom discourse.

School and Teacher Community. Infrastructuring is developed at school level for promoting teacher community. In line with tripartite school, university and government partnership, the provincial educational initiatives on technology-enhanced pedagogy reform creates a mandate for school improvement. The principal has identified knowledge building/creation for school development plan with technology support. Teacher professional development (PD) is grounded in knowledge building framework emphasizing progressive change and community. Teachers work as a community engaging in discourse within and cross-subjects, not just sharing good practice, but continually pondering challenges of principle-based pedagogy and student epistemic agency. Infrastructuring also involves teacher-researcher co-designs, teacher workshops and onsite support; teacher creating artefacts to help initiate new teachers; enables reflection for progressive growth, and support dissemination to peers in other schools.

International Teacher Community/Network. Infrastructuring for knowledge building also involves teachers connecting with the outside world. The Shenzhen teachers are involved in an international teacher network collaborating with Singapore teachers. A meta-space using KF, a cross-community PD space is designed to promote teacher inquiry and innovative practice. This meta-space design includes (i) KB teacher stories, (ii) student KF notes and artefacts, (iii) analytics report, (iv) scaffolds for teacher reflection and (v) KF view for collective inquiry. Teachers gained new insights via creating KB stories, building knowledge with others as they write on KF and participate in cross-community teacher meetings. Analyses of teacher KF notes in the cross-community view identified three themes (1) Principle-based approaches as focus for knowledge building practice, (2) KB stories as boundary object inspiring questions and reconstruction, and (3) Recognizing role of learning analytics for tracing students' idea development.

Across the multiple levels of infrastructuring for knowledge building innovation, emphasis is placed on progressive improvement and community growth. Students continually developed new ways of thinking about knowledge and their identity as knowledge builders; teachers supported by school ethos for pursuit of collective inquiry; cross-community teacher networks enabled boundary-crossing for rich fertilization of ideas. Changes in classrooms, school and network levels are brought back to other levels for new practice and sustained innovation. Analysis of infrastructuring at multiple levels would help us understand more about the socio-cultural-technological dynamics of innovation as well as providing possible parameters for realignment and designing emerging knowledge building innovation.

Significance of the symposium

This symposium contributes to the learning sciences by demonstrating infrastructuring practices involved in sustaining Knowledge Building across settings. Infrastructuring has emerged within design-based research as a lens to move away from static views of infrastructure and instead acknowledge the process of dynamically renegotiating infrastructures (Karasti & Syrjänen, 2004). Studies presented in the symposium approach infrastructuring from different angles, including existing practices and beliefs as system inertia (Scardamalia & Bereiter), structural constraints such as class size (Hod et al.), teacher lesson planning as an essential practice (Zhang & Park), technological shifts caused by disruptions (Oshima et al.), technological innovations to enhance student agency (Teo et al.) and pervasive knowledge building (Chen et al.), and multi-level infrastructures (Chan et al.). By situating Knowledge Building within organizational structures and social-technical systems, these studies reveal "patches" of infrastructural work key for launching and sustaining KB initiatives. Collectively, these studies demonstrate the promise of making infrastructure a visible part of our work and making intentional efforts to transform or create infrastructures that facilitate KB.

The significance of this symposium is twofold. First, surfacing infrastructures and infrastructural work in KB initiatives could create new entry points for educators who aspire to contribute to the vision of education as knowledge creation. Second, learning scientists are confronted with challenges with reimagining education. By contributing concrete cases of infrastructuring from novel settings, this symposium offers examples of infrastructural transformation that involves changing constellations of structures and practices. The symposium serves as a point of departure for future work to reimagine education infrastructures for Knowledge Building and other ambitious educational practices.

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