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Knowledge Building as New Perspective for Education

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Editorial

Knowledge Building as new perspective for Education: From belief mode to design mode and the need for ‘infrastructuring’
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Infrastructuring for Knowledge Building: Advancing a framework for sustained innovation

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Abstract

Despite the wide implementations and extensive research base that has developed on knowledge building communities, continued efforts are required to address the challenges of implementing innovations in diverse contexts as well as sustaining them over time. In this paper, we draw on the idea of infrastructuring as an emergent, multi-level approach that can shed new light on ways to do this. After defining the notion of infrastructuring and showing its unique potential to sustain knowledge building, we examine three cases of infrastructuring within the context of efforts to grow knowledge building innovations in existing educational ecologies. This paper offers some new insights into how infrastructuring can be conceptualized to expand and sustain knowledge building innovations.

Keywords: Emergent, Knowledge Building, Infrastructure, Infrastructuring, Sustainability

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Introduction

The theory and practice of knowledge building is one of the most well-known and influential educational approaches aimed to address emerging needs of engaging students in knowledge creation in a world of transition (Chan & van Aalst, 2018). Despite the wide implementations and extensive research base that has developed on this approach, continued efforts are required to make knowledge building more achievable than it is now, so that its reach can be extended to a wider range of students, school practitioners, and researchers in diverse contexts. To deal with the challenge of sustainability and scalability in the implementation of learning innovations, Penuel (2019) introduced the concept of educational infrastructuring – “activities that aim to redesign components, relations, and routines of schools and districts that influence what takes place in classrooms” (p. 659) – which creates conditions that support educators in making innovations into “working infrastructures” for organizing learning activities (p. 659). This article explores infrastructuring for sustaining knowledge building as an educational innovation that embraces dynamic interactions and emergent knowledge processes.

Two knowledge building infrastructures stand out as central reifications in the international knowledge building community for creating and sustaining knowledge building endeavors across a number of settings. The first infrastructure is the set of 12 knowledge-building principles (Scardamalia, 2002) that provide a compass for implementers as they design supports for their knowledge building communities given the affordances and constraints of their local settings. The second is Knowledge Forum (KF), a proprietary technology developed by knowledge building researchers (Scardamalia, 2004), which structures idea advancements through many of its components and functions: trees of build-on ideas; scaffolds for making diverse types of contributions; notes that turn different colors when one reads through ideas within the community; rise-above notes that elevate discussion to higher levels etc. (Zhang et al., 2019). The principles and Knowledge Forum are infrastructures because they are actively incorporated to create conditions for knowledge building communities. In the
meantime, both infrastructures are also improvable ideas in light of new challenges spawning from a complex, rapidly changing world, motivating the global knowledge building community to continuously improve them. Our goal in this paper is therefore two-fold: to advance our discourse on why we need to think about infrastructures and infrastructuring, as well as consider what challenges and approaches exist on infrastructuring for knowledge building.

To address these questions, we start this paper by turning our attention to the ideas of *infrastructuring* (Penuel, 2019) as a way to explicate some recent conceptual advancements on the dynamic and ongoing transformation of knowledge building endeavors that need to be designed with emergence in mind. After laying the theoretical grounds for how to think about these ideas and why they are important, we explore innovations in knowledge building infrastructures that have grown in exciting directions over the past few years. We relate these to Chen’s (2022) framework, which explores six strategies for effective infrastructuring. We rise above these examples to shed light on how infrastructuring can support knowledge building.

**Why knowledge building infrastructuring?**

Despite the development of various conceptual and material infrastructures within the knowledge building community, the actual notion of *knowledge building infrastructures* has not been a widely used conceptual artifact to-date. Rather, knowledge building research has examined supports for knowledge building through the lens of socio-cognitive and technological dynamics (Zhang et al., 2007), without invoking this useful notion. We believe that the unique perspective brought out by the metaphor of infrastructures and infrastructuring provides new ways to address the challenges of implementing knowledge building innovations in diverse contexts as well as sustaining them over time (Zhang et al., 2011).

The idea of infrastructures in educational contexts shares similarities with other concepts, such as scaffolding (Reiser & Tabak, 2014), the zone of proximal development (Vygotsky, 1978), and apprentice-
ship (Rogoff, 1990). We draw distinctions here to clarify the meaning. These latter concepts all share the central concern with infrastructures in supporting aspects of learning (or knowledge building). However, scaffolding and related ideas are meant to support increasing self-sufficiency of individuals such that the supportive element can sometimes be partially or completely faded away over time. For example, scaffolds within Knowledge Forum provide a list of meta-cognitive terms (e.g., “An alternative theory”) to help students become more intentional about what ideas they contribute and how they connect to existing ones (Scardamalia & Bereiter, 1994). With continued use, connecting to others’ ideas and being explicit about how new ideas may advance them are enculturated by students and therefore the list of scaffolds themselves may no longer be needed.

Even though these concepts have similarities, the idea of infrastructures offers a unique and powerful metaphor by emphasizing the larger scale of supports that are used for communities or collectives and which are more long-lasting. This becomes evident when doing a Google image search for the term “scaffold” and finding pictures of individual buildings being supported by temporary bars and platforms, versus searching for “infrastructures” that bring up roads and bridges with many cars, or energy grids that are used to support cities or large populations of people in ways that require considerable investments for long-term use. Therefore, the metaphor of infrastructures generally invokes deeper, wide-ranging work at the community or systems-level that is more sustainable, such as data infrastructures, physical infrastructures, and technological infrastructures (Slotta et al., 2013). Despite their size and scope, these infrastructures are adaptable, such as building new technologies on existing ones. As an example, in knowledge building scholarship and practice, the Idea Thread Mapper adapted the technological infrastructure of knowledge building by providing new functionalities (on top of Knowledge Forum) to address emergent issues such as how to connect between different classroom communities that build knowledge on similar topics (Yuan & Zhang, 2019).

This distinction is important to recognize in the context of knowledge building efforts. Researchers who have focused on infrastruc-
tures in ways that are relevant for knowledge building have taken into account the scale and sustainability inherent in this metaphor. For example, Bielaczyc (2006) described four dimensions of social infrastructures that frame the critical social design elements of classrooms, including cultural beliefs, practices, socio-techno-spatial relations, and interaction with the outside world. These dimensions are deeply embedded and far reaching, touching on all aspects of the larger ecosystem. Others, such as Star and Ruhleder (1996), view infrastructures at a similar scale, as being embedded in socio-technical structures that shape and are shaped by rules and conventions in a community. Edwards (2010) similarly views infrastructures for knowledge production in the context of research communities, defining them as “robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds” (p. 17). These perspectives highlight the scope and scale of infrastructures, inextricably making them relational and oriented towards a systems level.

In recent years, the idea of infrastructuring has been appropriated by learning scientists as an innovation on the metaphor of infrastructures. By shifting the metaphor from a noun to a verb, the dynamic and ongoing nature of this concept is emphasized in a way that stresses their need for emergent designing at the systems level. Penuel (2019), for example, points out that design-based research is good at creating “hothouse” conditions where innovations flourish in the short-term but are typically not sustainable. He goes on to suggest that infrastructuring requires coordinating activity across levels and organization of an educational system – such as curriculum, assessment, and teacher professional development – so they are in relation with one another and can therefore work together. This often requires dealing with unanticipated changes, such as sudden bursts of activity, that require attention and intervention. Infrastructuring is carried out by creating research-practice partnerships (Coburn & Penuel, 2016) with those in authority to shape the existing infrastructures with the aim of building capacity, making instruction more coherent, aligning policies and practice, and disrupting norms that reproduce inequities and therefore marginalize specific groups. It is consistent with the
goals and focus of design-based implementation research, which is concerned with developing theory and knowledge about implementation efforts as well as developing the capacity to sustain change within systems (Fishman & Penuel, 2018). Penuel (2019) describes a long-term partnership between the University of Colorado Boulder and Denver Public Schools that ultimately built a cadre of leaders both inside and outside of classrooms to support one another, expanded the reach of the innovative program to many schools and grade levels, and created new assessments that supported existing teacher evaluation systems instead of coming into conflict with them.

To sum, infrastructuring is a new concept that is important to explore as it emphasizes the multi-leveled and dynamic approaches necessary to create long-term, sustainable knowledge building endeavors in ways that are not addressed by the current set of knowledge building principles. It moves the knowledge building community a step forward in thinking spatially and temporally about what designers need to attend to, as well as what types of relationships between students, teachers, school managers, policy makers and with knowledge work in the broader society are important to foster in order to achieve these results.

**Challenges and approaches to infrastructuring for knowledge building**

As its name applies, knowledge building is an idea-centered educational approach (Scardamalia, 2002) that builds on a tradition of using computers to support the development of a knowledge-creating community (Scardamalia & Bereiter, 1994). The set of knowledge building principles and Knowledge Forum have therefore followed suit in having these epistemic and technological foci. Still, various researchers have pointed out that supporting knowledge building also entails other, non-epistemic goals which are not solely technology-reliant, such as belongingness to a community (Cohen & Hod, 2021). Therefore, knowledge building infrastructures should be viewed multidimensionally in ways that align with the broader view of infrastructuring in complex environments. While literature on infrastructuring lacks sys-
tematic and concrete guidance on how to infrastructure, Chen (2022) has developed an initial framework with six inter-connected strategies or practices. These include (1) Identify key social actors and spheres of design activities; (2) Surface important components of existing infrastructures as well as their relationships; (3) Anticipate and design for possible points of infrastructuring; (4) Engage in coherence-making activities; (5) Engage in meta-design and capacity building; (6) Continually evaluate infrastructuring using appropriate methods.

With an eye on contributing new ideas that can advance our understanding of how to sustain innovations through infrastructures and by infrastructuring, this section explores challenges and approaches of doing this in ongoing knowledge building research. Our examples include orchestrating idea improvement through orchestration graphs, fostering growth orientations, and flexible technological infrastructures for teacher knowledge. Following our exposition of these three cases, we rise-above them to make some general insights about these challenges and approaches in relation to Chen’s (2022) framework.

Infrastructuring and orchestrating idea improvement in knowledge building communities and design studios

The student Knowledge Building Design Studio (sKBDS) is a design and discourse space specifically crafted to support idea sharing within knowledge building communities, composed of teachers, students, researchers, and industrial experts (Teo et al., 2022a). The sKBDS brings together heterogeneous groups of students beyond the classroom into an authentic learning environment where they role-play as scientists to engage subject matter experts and researchers in authentic inquiry activities and develop theories with reasoning strategies and idea development. Infrastructuring practices within the sKBDS involves clear identification and understanding of the relationships between the social actors (all participants are co-contributors of ideas), authentically designed activities (e.g., debates on sustainability issues), and the use of existing technologies (KF and others), as evidenced in other similar knowledge building contexts (Teo et al., 2022b).
An aspect of infrastructuring in sKBDS involves integrating *orchestration graphs* (Dillenbourg et al., 2009) into authentic learning environments to increase the visibility of infrastructures and understand how they are implemented (Teo et al., 2022a). Orchestration graphs illustrate the key stakeholders, activities, and relationships between activities (Chen, 2022), as can be seen from a two-day sKBDS (Figure 1). The horizontal axis represents the timeline, and the vertical axis refers to the multi-level spaces (individual, group, community) within the sKBDS. Key events and stakeholders are represented using rectangular boxes, with arrows between boxes illustrating the sequence of activities for knowledge creation and sharing across the spaces. Taking a design-based approach, researchers initiate designs and receive feedback, reflect on the research gaps, and update the designs in the orchestration graphs. Likewise, by taking on a reflective structuration approach (Zhang et al., 2018), students act as agents for infrastructuring by co-creating the shared inquiry structure, as part of the process of a research cycle, to guide their ongoing knowledge building processes. Ultimately, orchestration graphs have been shown to result in a rethink across different levels of learning and also impact teaching practice (Lee et al., 2022).

**Figure 1.** Example of an orchestration graph for a 2-day sKBDS
An example of the way orchestration graphs was used in an sKBDS occurred in June 2022, when over 50 teachers, students, international experts, and researchers shared and improved ideas via virtual meetings and the KF over three days on the theme of sustainability. The Journey of Thinking (Yuan & Zhang, 2019) was used to support students’ continuous idea development and reflection, giving rise to big ideas and aligning to principles for KB infrastructuring. Through the illustration of an orchestration graph and use of scaffolds in the Journey of Thinking (e.g., we used to think), it showcased how an inquiry cycle that addresses and resolves real-world problems can be sufficiently facilitated with resources from experts, further explored through design activities, and deeply debated via knowledge building discourse.

As a partial solution to how one can address idea trajectories and development across a sKBDS, the orchestration graphs were used to unpack the key components of knowledge building and idea improvement across different levels of a knowledge building community. By bringing in emergent group mechanisms (Yuan et al., 2022), such as allowing students to post personal questions to relevant areas that they are interested in and thus be able to form small working groups that are centered on emergent needs, students’ high-level agency and flexibility can be encouraged, and the integrated use of an orchestration graph allows one to orchestrate sophisticated collaboration among learners in a sKBDS.

**Fostering a growth culture to support knowledge building by infra-structuring**

Over the past decade, the notion of Humanistic Knowledge Building Communities has been developed to emphasize the non-epistemec (humanistic) infrastructures that can support knowledge building. Recently, Kashi and Hod (2022) investigated how to foster growth-orientations in such an environment based on the contention that as participants grow as people, the ideas they contribute and thus the community knowledge space can advance as well. They used this to
implement a knowledge building community that intentionally fostered a growth culture, rising above existing scholarship dealing with fixedness and growth (e.g., Dweck, 2006) to offer a comprehensive framework that delineated several dimensions of this culture.

The humanistic perspective underlying the infrastructure was based on person-centered principles such as providing unconditional positive regard to others, listening emphatically, and being genuine in relationships (Cornelius-White, 2007). This required an emergent design to deal with conflicts as they came up, tensions that existed within the group, and sociocultural differences that became apparent as students expressed themselves more fully in the community. Thus, fostering a humanistic culture required a dynamic infrastructure to support knowledge building.

While Kashi and Hod (2022) found evidence that this approach supported the knowledge building endeavor – a claim supported in similar research (Hod & Katz, 2020) – it was set in a higher education context where they had the leverage to align the infrastructures that supported the program, such as assessment, space, the curriculum, and the person- and idea-centered cultures. In a pilot study set in a local middle school, the experience was far different. Although many of the participants engaged in rich knowledge building and on the whole the implementation was viewed successfully by the students, participating teacher, and school administration, the co-designers (which included Kashi, Hod, and others) felt the limitations of the approach compared to the higher education contexts. They attributed this gap to the lack of infrastructuring across the school community: The intervention was isolated to one classroom, the principal was supportive but did not fully grasp the approach, parents were relatively uninvolved, and the students’ advisor openly criticized the pedagogy in front of the students. Thus, the researchers concluded that the implementation approach in future years had to foster family- and community-engagement (Ishimaru, 2019) through a research-practice partnership (Coburn & Penuel, 2016), whereby parents, school administration, the teaching staff, broader assessment practices, and so on needed to be part of the infrastructuring process.
Infrastructuring for teacher knowledge building in the information age

A comprehensive study of 39 knowledge building initiatives led Zhang et al. (2011) to conclude that in addition to the design of sophisticated technologies such as the Knowledge Forum, successfully implementing an educational innovation also requires teachers to alter their professional identities and assume the role of knowledge builders (see also Scardamalia & Bereiter, 2016). In this section, we argue that positioning teachers as creators – not just consumers – of professional knowledge can be understood in terms of infrastructuring. We illustrate this claim by discussing Sefaria, an online tool that was designed to play a key role within an ongoing effort to revolutionize the field of Jewish education (see Cohen et al., 2022).

In the past, textbooks and teachers’ guides were viewed as the primary infrastructure for disseminating teacher knowledge, including content knowledge, pedagogical content knowledge, and more (e.g., Ball & Cohen, 1996). Using books as a means of communicating with teachers means positioning them as passive end users because print is a medium that only supports one-way communication. However, the emergence of social networking in recent years constitutes a moment of breakdown in which infrastructures (which are typically hidden) become visible because they cannot support the types of activity that are now required. Such moments are good opportunities to engage in infrastructuring, a process that includes identifying key stakeholders and rethinking the ways in which they interact with one another, the roles that they fulfill within their activity systems, and the affordances of alternative technological infrastructures for mediating new types of consequential activity.

Sefaria “is a non-profit organization dedicated to building the future of Jewish learning in an open and participatory way” (www.sefaria.org/about). The site has two interfaces for interacting with hundreds of Jewish texts, which have traditionally only been accessible to a relatively small number of scholars. The library interface features a sophisticated search engine, where clicking on any passage opens a sidebar with links to all other passages throughout the corpus that cite the selected one or are cited by it. In addition,
Sefaria includes a source sheet interface. Source sheets are blank documents that users can populate with texts, images, and videos that they upload or link to. Recontextualizing canonical texts in this way constitutes a powerful meaning-making activity that allows users to generate novel ideas and interpretations. Both interfaces – the library and source sheet – are integrated with one another, meaning that users can search or navigate the library from within the source sheet interface and add select passages to their sheet.

Sefaria’s ultimate aim is to alter the relationship between teachers and Jewish texts by positioning them as knowledge creators, rather than mere consumers. In the past, most teachers of Jewish studies did not possess the expertise required to interact directly with primary sources, instead relying on experts to disseminate content knowledge and lesson plans. By repositioning teachers as creators and disseminators of content knowledge, we view the launch of Sefaria as an act of infrastructuring, which is intended to mediate this shift and have a broad social impact.

**Advancing a preliminary infrastructuring framework for knowledge building: A temporal dimension**

The consideration of these three examples sheds light on effective strategies “that aim to redesign components, relations, and routines of schools and districts that influence what takes place” (Penuel, 2019, p. 659) in knowledge building communities. Each of these examples highlights how specific strategies can be instantiated and therefore draws out new aspects of the implementation framework. The first example appears aligned with Chen’s (2022) first two strategies; the second example coincides with the third and fourth strategies; and the final example demonstrates and explicates the fifth strategy.

In the first example, the orchestration graphs help to identify key stakeholders and design activities (strategy 1). This is a foundational stage and practice because without being explicit about the participants and setting, it will be difficult to comprehend what requires infrastructuring. Therefore, orchestration graphs are an excellent ex-
ample for how to do just this, with the added novelty of allowing the multi-level actors to surface the key infrastructures and understand who is doing what at different levels of the design studio (strategy 2).

The third and fourth strategies of Chen’s framework align well with the second example, which draws on humanistic practices that view social failure as potentially productive, when facilitated following growth-promoting conditions (Hod et al., 2018). By creating norms where people can be their authentic selves, conflicts naturally arise. These conflicts typically reveal the “points of infrastructuring” in Chen’s framework (strategy 3). Meaning, conflicts that arise can be seen as signals for underlying tensions, opening the possibility for all those involved to take the responsibility to resolve. Whereas in many cultural practices, conflicts are avoided, growth-promoting practices encourage deeper reflection and sharing, empathic listening, and acceptance without judgment with the hopes of developing deeper understandings as to the roots of conflicts and finding ways to solve them. Issues that often build up to create these tensions are therefore reframed, are having productive potentials, and are actively explored in a growth-promoting culture, in what can be considered coherence-establishing activities (strategy 4).

The third example of the way the Jewish education community developed a new, dynamic, and flexible platform following a breakdown provides a coherent example of capacity building and meta-design through infrastructuring. Sensitive to the breakdown that the community underwent as contemporary calls to democratize Jewish identity, culture and knowledge were increasingly voiced, the community developed a sophisticated technology that makes canonical texts more accessible and allows teachers to fundamentally change their roles. This type of repair work, aimed to allow everyone to design in ways that are customized and tailored to new contexts, is vital to successful infrastructuring (strategy 5).

Looking across these examples, a general pattern emerges whereby the strategies appear to have a temporal mechanism, roughly aligned with theories of group development. Specifically, stage models (Arrow et al., 2004) assert that groups generally progress through forming, storming, norming, working, and final stages. In supportive groups,
the forming stage entails allowing participants to act authentically in part to allow full participation by all members. Just like in the first example, efforts are made to understand all the participants, including those who are dominant or marginalized. Therefore, the strategy of identifying the participants and activities is something that generally happens in the beginning as a vital aspect of being in the forming stage.

The second example draws out what continued infrastructuring strategies are required in the face of breakdowns or tensions. This is akin to the storming stage of group development, which sees challenges and failures as both necessary and productive if approached in the right way. The outcomes of breakdowns involve developing new norms (norming stage) in ways that make room for multiple voices to be heard, giving all participants and stakeholders ownership over the process. This is indeed what we saw in the third example, whereby the community adapted their technological infrastructure in order to deal with the changing landscape that allowed teachers to be active in the knowledge building endeavor, ultimately developing a new infrastructure supporting an expanded set of creators.

While the correspondence of Chen’s framework to group development stages is not perfect, it does suggest that infrastructuring for knowledge building may have some general temporal characteristics that inform, and can be informed by, other literatures. In particular, Chen’s inter-connected strategies or practices appear to fit a progression that coincides with stage theories of group development. That is, the strategies or practices may be best enacted in correspondence with the development of groups. Of course, groups can move forwards and backwards, and often show traits of several stages at once. Therefore, the strategies or practices may need to be enacted repeatedly. But, the general progression for productive and sustainable groups is a near universal principle of group behavior and thus we may expect the ideal way to implement these strategies would be to follow the same general progression. This opens up opportunities to consider infrastructuring across a new dimension, with consideration to the emergent needs of the knowledge building community at any one time and with some knowledge of how the general pattern of development may unfold.
Conclusion

Infrastructuring is a relatively young idea in the learning sciences that has a strong potential to assist in the efforts of making large-scale, sustainable change for education innovation. This perspective is clearly relevant to the knowledge building community, which seeks to design and implement a fluid innovation across large systems worldwide. By considering three examples of knowledge building infrastructuring in relation to a framework that elicits strategies and practices for infrastructuring, we were able to make some new insights into how to do so productively. Our first example showed how particular artifacts could be used to identify key participants and activities across levels. The second example described the growth culture of family and community engagement necessary to cultivate to deal with the challenges, obstacles, and setbacks that are often present in large systems and when seeking to improve infrastructures. Our final example showed how infrastructures could be changed when successfully addressing breakdowns. Together, these highlight a general temporal pattern of development that may be typical of growth and change efforts through infrastructuring. Future research in knowledge building can examine how these strategies are used at different times within the context of the implementation of knowledge building innovations.

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