Co-construct Learning Spaces to Sustain Collaborative Knowledge Building During COVID-19

Thomas Underwood, University at Albany, State University of New York, tunderwood@albany.edu
Hyejin Park, Korea Institute of Science and Technology Information, hpark7@kisti.re
Jianwei Zhang, University at Albany, State University of New York, jzhang1@albany.edu

Abstract: This study draws on a learning ecologies framework to explore how the teachers and students in a Grade 5 knowledge building (KB) community co-constructed new learning spaces to sustain their science inquiry during COVID-19 school closures. Using an interactional ethnographic approach, we conducted detailed analysis of observation notes, videos of whole-class meetings, and students' online discourse. Our analysis indicated students showed sustained engagement in KB discourse during the school closures, which took place in new learning spaces co-constructed by the teachers and students. The co-construction of learning spaces involved replacing some of the critical classroom-based elements with new options, accommodating the limitations they faced while drawing on new opportunities for students to conduct inquiry in the broader world. Student KB was sustained by a learning culture and activity system formed around the principles of KB and use of relational resources.

Introduction

Schools are local ecosystems of activity situated in a new world of rapid change, complex challenges, and digital connectivity. As a result, there is renewed focus on how to cultivate collaborative, creative, and adaptive competencies in students as they navigate and actively shape school-based and broader ecological systems of social interaction (Gutierrez & Barton, 2015; Sawyer, 2015; Lemke, 2000). Accordingly, various collaborative, inquiry-based learning programs aim to develop students' abilities and habits of mind that are essential to collaborative problem solving and knowledge building (KB). Beyond adopting externally designed inquiry-based learning procedures and collaboration tools, teachers and students must take on high-level agency and ownership to continually adapt and improve their inquiry-based practices in changing contexts (Clarke & Dede, 2009; Coburn, 2003; Zhang et al., 2011). In recent years, the COVID-19 pandemic led to nationwide school closures and temporary suspension of formal learning in schools. In this study, we analysed a Grade 5 science inquiry program that continued during the school closures. This inquiry offered a window to view how students and their teachers create 'new social and material configurations' (Damsa & Jornet, 2017) for collaborative KB when facing uncertainty and challenges.

Theoretical framing

This study adopted a learning ecology framework to analyse how students and teachers co-construct new learning spaces for collaborative KB in a disruptive environment during the COVID 19 pandemic. We define learning spaces as the physical or virtual location where human and non-human material interact to mediate how learning takes place. The ecological perspective conceptualises learning spaces as co-constructed by learners through emergent interactions facilitated by pedagogical arrangements, tapping into various ecologies of resources (e.g. intellectual, relational, or digital) (Brown, 2000; Damşa et al., 2019). Students play a substantial role in co-configuring the learning spaces through reflexively working together in situated activity (Goodyear, 2020). Learning spaces as systems of interaction (Dewy, 1997; Bronfenbrenner, 2009; Hecht & Crowley, 2020) are sustained and modified through members' participation in relation to their social, cultural, and political context (Barron, 2006; Lemke, 1995). Members' agentic participation may lead to expansive and transformative changes in learning spaces, resulting in boundary crossing in terms of people, space, time, and resources (Damşa et al., 2019; Yuan & Zhang, 2019) and re-structuring of situated activity, norms, and objects that act as relational resources (Vyygotsky, 1979; Engeström, 1987; Tsui & Law, 2007). Such relational resources include the physical and intellectual material that contribute to the continuity and change in social practices, as determined by social, digital, historical, and cultural relations (Damşa, et al., 2019).

The science inquiry program analysed here was organised using a Knowledge Building (KB) approach. KB represents a collaborative, inquiry-based pedagogy that aims to transform classrooms into knowledge-creating communities (Scardamalia & Bereiter, 2006). KB communities operate on a set of principles that encourage students to take on high-level responsibility and epistemic agency: to co-construct inquiry goals, generate and improve ideas, identify and make constructive use of resources, and contribute to the structuring and maintenance of spaces for dialogue across social, spatial, and temporal boundaries (Scardamalia, 2002). The inquiry processes are not pre-scripted but continually unfold and are improvise based on students' emergent interests, needs and ideas (Zhang, et al, 2011). Through interacting around shared questions and ideas, students identify and work on emergent inquiry goals, form opportunistic groups, and co-organize their inquiry processes and learning spaces in reflexive and resourceful ways (Hod et al., 2019; Siqin, van Aalst & Chu, 2015; Zhang et al., 2009, 2018). While the co-construction of learning spaces often takes place as a gradual process around relatively stable school structures, the drastic shift of learning arrangement during COVID-19 school closures provides a unique window to view co-construction processes when a learning community is faced with uncertainty and challenging circumstances.

This research aimed to understand how a group of Grade 5 students and their teachers co-constructed the operational and structural aspects of their learning spaces to sustain their collaborative KB during the global pandemic. Our research questions asked: RQ1: What level of KB work was conducted in the remote learning unit, when compared to earlier units in the school year? RQ2: How did the KB community co-construct its learning spaces, configuration, and resources to sustain science inquiry when faced with uncertainty and challenging circumstances?

Method

Participants and classroom contexts

This study analysed the implementation of KB practice in a community of fifth graders facilitated by two teachers at a public elementary school in the Northeast US. The teachers--Mrs. G and Mrs. T--were experienced teachers and had worked with our research team to implement KB for eight and two years, respectively.

In the school year 2019 to 2020, Mrs. G and Mrs. T taught science in four Grade 5 classrooms with a total of 82 students (ten-to-11-year-olds). Before the school year began, the teachers participated in a co-design workshop organised by our team. The teachers reflected on their classroom practices in the past year and envisioned opportunities to facilitate more productive science inquiry considering the KB principles (Scardamalia, 2002). The science standards (NGSS Lead States, 2013) listed four areas of study for Grade 5: Ecosystems, Water, Matter, and Space. Considering the time scheduled for science in the school, the teachers planned for three areas: Ecosystems (fall), Water (winter), and Matter (spring). Between September and March, the teachers facilitated students' inquiry about ecosystems and water, adopting the principles and practices of KB. Each inquiry unit 'kicked-off' with a set of exploratory activities (e.g. a school courtyard observation) which triggered students' interests, initial ideas, and wondering. Students then participated in a whole class metacognitive conversation ("Metacognitive Meeting") to share their questions, formulate shared wondering areas (inquiry directions), and to plan inquiry actions. The community conducted various activities to address their questions, including experiments and observations, personal research using various sources, face-to-face group work, whole-class discussions, and in-class time for students to post notes on the online collaborative learning platform: Idea Thread Mapper (ITM, see https://idea-thread.net). The students could choose what they worked on and with whom. The teachers interacted with students daily to understand their evolving inquiry interests and progress, soliciting student input to co-structure emerging inquiry goals, activities, and group efforts.

In mid-March 2020 when COVID-19 cases rose, the local government announced school closures. The school involved in this research made a quick transition to remote learning. Science in the elementary grades was not considered a mandatory subject to be continued. However, the two teachers decided to offer a voluntary science unit. The teachers made the choice to change the inquiry topic in spring to Space after recognising the difficulty for students to study Matter without access to experimental kits. A total of 29 students participated in this voluntary Space unit. Detailed processes of how the Space inquiry was constructed is analysed in Results.

Data sources and analysis

The data sources in this study included classroom-based and virtual observations of each science lesson during the school year 2019-2020, video/audio recordings of whole-class discussions, records of online discourse using ITM, and recordings of teacher meetings in which they planned the science inquiry. Our research team observed each science lesson and created a documentation of the classroom events, which were indexed and mapped chronologically to guide further analysis.

Our analysis adopted an interactional ethnography approach, which provided the logic of inquiry for investigating what learners construct in a temporal sequence of events as viewed through multiple levels of analysis (Green & Bridges, 2018). We consider learning as a socially constructed process in which individuals propose and develop meaningful interactions, and activities across configurations of actors, times, and events (Green & Bridges, 2018). Therefore, we analysed students' space inquiry in relation to their inquiry work undertaken earlier in the school year to understand how the community sustained and adapted its KB practices. This analysis attended to how micro level events in the distance learning unit were part of a broader social co-construction of the learning norms, expectations, and routines that took place over the academic year.

Specifically, we first reviewed the data collected to construct a whole picture (timeline) of the inquiry processes across the three science units in the school year. A quantitative analysis was conducted to examine the KB work conducted in the Space unit based on online discourse, building on their KB practices in the two classroom-based science units. Qualitative analysis of the classroom observations conducted for each unit identified the core KB activity patterns and resources introduced to the community such as face-to-face metacognitive meetings, online work on ITM, and specific classroom norms/expectations (e.g. discussions around features of a good online ITM post). We then narrowed our focus to the Space inquiry conducted during the Covid-19 school closures. We used qualitative data analysis to understand how the teachers planned the Space unit and how the learning community co-constructed inquiry spaces and used resources to reconfigure their KB activities and discourse. The focus of the analysis included the teachers' co-planning document and video-recordings of the first three whole class online meetings conducted using Google Meet. The videos were transcribed and coded following a grounded theory approach (Strauss & Corbin, 1998). In coding, emergent themes were identified, adapted, collapsed, and expanded with reference to the multiple data sources and chronology resulting in two main themes related to co-construction of learning spaces. These include (a) Forming KB norms and expectations, (b) Co-construction of inquiry resources in, as, and across learning spaces. Each theme included a set of subthemes and codes that captured various aspects of learning spaces co-constructed by the teachers and their students.

Results

What level of KB work was conducted?

To address RQ1, we conducted a quantitative analysis of student participation in the online KB discourse in the three science units. As Table 1 shows, the 29 students who chose to participate in the voluntary Space unit contributed a total of 126 notes, with each contributing an average of 4.34 notes. Considering that this unit lasted over a much shorter period (six weeks) and was not mandatory, the contribution rate shows students' active contribution, which was equivalent to that in the previous two units. Also, a higher proportion of students (23 of the 29, or 79.31%) built on their peers' notes in the Space study than in the Water (34 out of 73, or 46.58%) and Ecosystem unit (41 out of 72, or 56.94%).

Table 1

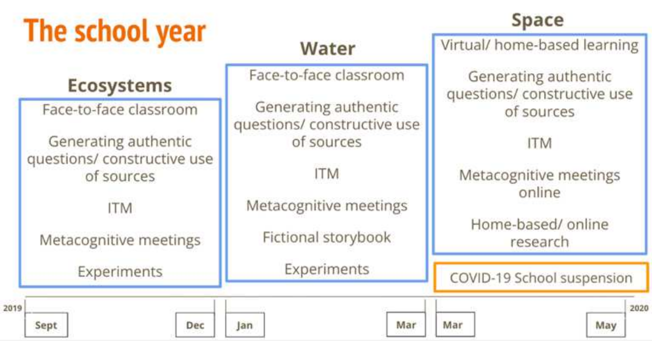
Students' participation in ITM for the three inquiry units over the 2019-2020 school year

Inquiry unit	"Wondering areas"/Inquiry themes	Student participants	Online posts (total and average per student)	Build-on responses
Ecosystems (Sept to Dec)	Living and non-living things; energy and matter in ecosystems	72	398 (5.53)	83 by 41 students
Water (Jan to Mar)	Sources of water, human impact, solution to water problems	73	347 (5.12)	126 by 34 students
Space (Mar to May)	Earth, moon, solar system, space exploration	29	126 (4.34)	50 by 23 students

Tracing of KB activity patterns and resources across the three units

To address RQ2, we first analysed the development of the KB activity systems across the three science units. As noted earlier, KB pedagogy does not offer a standard sequence of inquiry activities. The teachers in this study worked with their students to develop major activity patterns in light of their inquiry goals and the KB principles. Figure 1 shows the major activity patterns and resources involved in the face-to-face and virtual spaces across the three units. When the Ecosystem unit started in late September, the students went through a transition as they were first introduced to the KB pedagogy. While the teachers had used the KB pedagogy for several years, the students were new to KB and therefore needed to adapt to classroom norms, expectations, participatory roles, and routines. Major inquiry-based activity patterns were gradually introduced guided by the principles of KB. Students were encouraged to generate authentic questions to drive sustained inquiry. As a major part of KB discourse, whole class “metacognitive meetings” were introduced and scaffolded by the teachers’ modelling. The community sat in a circle to conduct interactive and reflective conversation during which they shared and built on one another’s questions/ideas, reflected on progress, and formulated directions for further inquiry. To generate and improve their understanding, students conducted personal and small group research using notepads and science books in the classroom and resources from the school library. A set of science experiment kits aligned with the Ecosystem and Water unit was made available to students to support hands-on observations and experiments. Extending their face-to-face discussion and inquiry, ITM was introduced in September as a collaborative online space organised around student-generated inquiry questions and interests (Wondering Areas). As part of metacognitive meetings, students reflected on their KB practices and discussed how to take notes while reading, how to write ‘good’ online posts, and how to ‘work like a scientist’ to conduct research. The combination of individual, group, and whole classroom activities involving face-to-face and online interactions gave rise to the overarching classroom flow. The configuration of KB activity patterns and resources carried into the Water inquiry, with an additional feature of using a fictional storybook (about regions facing water shortages) to enrich the inquiry of science. During the Space inquiry conducted remotely, the teachers and their students had to make major adaptations to reconstruct the inquiry spaces and resources needed for collaborative KB. This included undertaking more personal inquiry activities that students could independently carry out at home; identifying and using more online resources in the absence of library materials; undertaking metacognitive meetings online using Google Meet; and exploring creative science observations at home (e.g. backyard moon and stars observations). ITM became the primary space for ongoing discourse and resource sharing among students and teachers. `

Figure 1
An overview of the science inquiry across the three units.



Co-construction of the learning spaces and resources in the Space unit

For a deeper analysis of RQ2, this section reports themes from our coding to elaborate how the teachers worked with the students to collectively co-construct and reconstruct the interactional and discourse spaces that had been nurtured and refined in the first two units. For the first level of analysis, the visible routines, practices, resources, and learning spaces used during the Space unit were investigated. Our analysis found the learning community continued to use ITM as a collaborative online discourse space; increased the use of Google docs for personal notetaking and organisation, and incorporated Google Meet as a synchronous communication space to conduct metacognitive meetings. ITM was a place to keep the conversation going through recording, sharing, and building onto ideas, questions, and sharing new pieces of information. Google Meet was the intensive and more immediate conversational space to raise questions, thoughts, and share information about the Space topic, and undertake the planning and metacognitive work. Google Meet replaced the previous face-to-face reflective dialogue regarding various metacognitive and logistical issues of their inquiry (e.g., what to inquire, how, who, using what resources), during the students and teachers made creative use of the newly available technological affordances. For example, students and teachers utilised the chat box function in Google Meet, which became an additional communication channel to interact with one another during the whole group oral meeting and connect their inquiry across learning spaces.

In response to the above observations, we further explored how these continuations, adaptations, and weaving of learning spaces and resource usage took place. The analysis gave rise to the following themes.

Forming KB norms and expectations: ‘add your piece to the puzzle’

Throughout the year, and specifically in the Space unit, the teachers made repeated reference to the importance of ‘adding your piece to the puzzle’ in the meta-cognitive meetings and ITM. In the kick-off event, for instance, the teachers shared a few slides on their computer screen to guide the class in planning the Space inquiry and to highlight their expectations for the students' roles. On the final slide, the teachers referred to the learning process stating, ‘We’ll be looking forward to hearing about your piece of the puzzle’. Similarly, in the final 10 minutes of the next video call on Google Meet, Mrs. G again shared her computer screen and displayed a wondering area for the Space unit in ITM using her web browser. A ‘wondering area’ represents a shared inquiry direction where students engaged in collaborative discourse to address the related inquiry questions (See Table 1). Showing an existing note from a student with the initial C in ITM, Mrs. G explained, “then you can build on to this, so I might ask C ‘what this is making her think?’, by sharing a fact only, it's like picking up the puzzle piece but it doesn't really help us to see where it fits into the rest of the puzzle, so I would ask C to share some more thinking there.” The teachers used the phrase ‘add you piece to the puzzle’ in previous units in both ITM and during meta-cognitive meetings communicating their expectations for collective responsibility for inquiry advancement. Throughout the year, the teachers referred to the same expectation across settings, building towards a norm for students to contribute to collective idea development through participating in collaborative discourse.

Alongside revisiting and maintaining the KB norms, the teachers further worked with students to develop more specific inquiry directions and related activity. Students discussed the types of activities they could do in their homes as new learning spaces and the topics and questions they could potentially research. The teachers suggested a few example activities such as using their backyard as an inquiry space to observe the sky at night, capitalising the word ‘OBSERVATION’ in their slides displayed via the share-screen function. The teachers also modelled a set of reflective questions for students and shared several example resources. They suggested that the students can use these links to find more information about the topic Space, though they did not state which resources to look at nor did they specify a particular order in which to view them.

From the beginning of the Space unit, the teachers invited the students to participate in the co-construction of content, resources, and the logistics of the inquiry. In the first metacognitive meeting, Mrs. T concluded by verbally asking the students if or when they wanted to have another meeting, if it had been helpful, and for things to discuss in future sessions. Opening the floor, the teachers gave the students an opportunity to participate in the inquiry planning process to which the students had many interesting ideas. Below is one example of several suggestions from the students.

> Mrs. T: I think it would be of interest to Mrs. G and I to know if, or when you guys would want to have another metacognitive meeting. Has this been helpful for your learning, or would you like to do something different for science? Where would you like to go next?
> D: How about articles and videos on space from National Geographic and some, how about some games, something mixing fun with education?

While the above conversation took place verbally, a few students in the video call simultaneously picked up a different part of Mrs. T’s question regarding the frequency of future synchronous meetings. These students used the chat box in Google Meet to share their thoughts as a side talk related to the logistics of their unfolding inquiry.

> A: I think that we could do this every week.
> M: Or every other week.
> A: That works too.
> G: Ok.

The video call concluded, the group said goodbye, and one student, ‘K’, stayed behind to follow up on a verbal comment they had made earlier in the meeting, but had not been picked up, regarding topics for future inquiry.

> K: Mrs. G, I was thinking outside the box, like asteroids and other stuff like dinosaur extinction
> Mrs. G: Oh yeah, a huh.
> K: Can we do that?

> Mrs. G: Right, there are some people who have those theories, don't they? So sometimes, that might be something that you do some study on as well.

Here, K clarifies the boundaries of what is considered acceptable or not when undertaking inquiry about the topic Space. The teacher acknowledges the possibility and the relatedness of the theory regarding linking dinosaur extinction and the topic Space, while appearing to remain neutral, thus allowing K to decide if and how they might pick up the new direction of inquiry.

Overall, the teachers made a continued and conscious effort to reinforce the KB principles of ‘Knowledge Building Discourse’ and ‘Community Knowledge/Collective Responsibility’ (Scardamalia, 2002) in the existing and new learning spaces. The teachers framed students' responsibilities in KB inquiry using the analogy of a puzzle, to which the students responded by taking up roles in the co-construction process.

Co-construction of inquiry resources *in*, *as*, and *across* learning spaces

A theme of coding emerged around the co-construction of inquiry resources in learning spaces. In response to teachers’ expectations and encouragement to co-construct the unfolding learning spaces, the students collectively made use of existing and new relational resources based on what was available to them both online and at home. Existing resources included ITM, websites, the teachers, students' prior knowledge, and the emergent ideas from the ongoing discussion as the inquiry discourse itself unfolded. New relational resources included Google Meet, the Google Meet chat box, backyard observations of the night sky from students’ homes, and videos and websites the students could access remotely such as National Geographic, and the NASA rocket launch live streams. With the removal of routine access to physical school-based resources, the community looked to their evolving learning spaces and interactions, both at home and digitally, for ways to use relational resources opportunistically and creatively as constituents of the developing learning spaces.

Through the identification of resources, the resources themselves often became learning spaces to sustain and further connect the inquiry processes. In the study, the teachers chose Google Meet as their main resource for the ‘face-to-face’ discourse. In the selection of Google Meet as a resource, it in turn became a learning space. Embedded in the Google Meet learning space, the chat box was a new relational resource the students and teachers opportunistically used to communicate in dynamic ways (e.g. new forms of side talk discussed above). The chat box resource in turn became a new learning space that was embraced as a place for side talk to gain access to and undertake content and process-related discourse. Through communicating a shared responsibility to find resources, the teachers mediated the ways in which the learning community not only sustained but expanded their opportunity to share ideas, pose questions, discuss logistics, and deepen their knowledge creation.

The learning community actively connected resources across their evolving learning spaces. As a form of signposting, the community referenced previous ITM posts, their independent browsing of websites, past conversations, and home activities as focal points to connect and guide their unfolding KB interactions. Figure 3 shows the first five minutes of the first Google Meet metacognitive meeting in the remote Space unit on April 15th. The first 5 minutes captured in the Figure consists of two episodes of talk focusing on student-generated questions (left and right columns). The cross referencing of inquiry activity and relational resources during the episodes are highlighted in orange. The internal connections within the discussion through direct verbal reference, or the use of the same terms and keywords in the episodes are signified with red arrows. In the second episode (on the right side of the figure) a student with the initial ‘A’ raised a question about colliding planets, which triggered several connections and references to past resource use and inquiry activity in ITM and the students’ home-based research. Mrs. G recognised that this conversation was related to ‘R’s previous post on ITM and asked, “Have you read R’s posts in ITM yet?”. One of R’s post on ITM, March 24th, was titled "The forces that act on the planets that help them stay in their orbits”, and three days later, March 27th, R added another post on ITM titled, “The gravity of the planets in the solar system” “(See Figure 2). Similarly, D, a classmate, recognised how A’s question related to their own individual home-based research using Google search. D added, “I was looking on Google... the gravity of the sun keeps all the planets in orbit and from colliding into each other.” By identifying related activity patterns across the locations, the community linked the resources and resource usage between learning spaces to pursue emergent wonderings as their face-to-face discourse unfolded.

Figure 2
R’s ITM posts referenced by Mrs.G in the meta-cognitive meeting

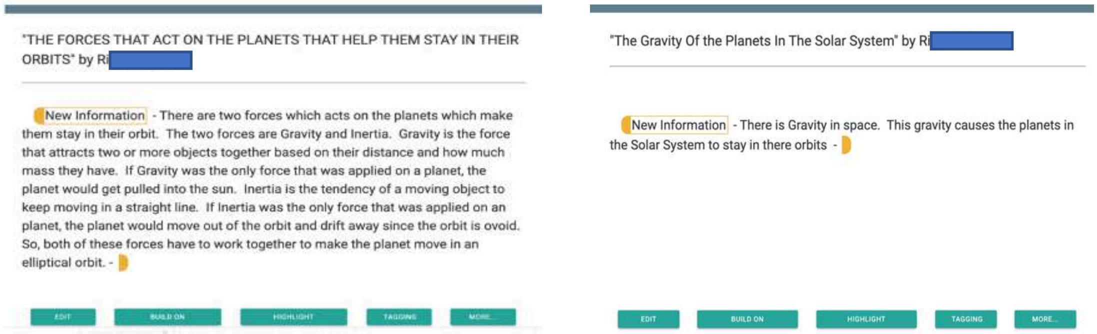
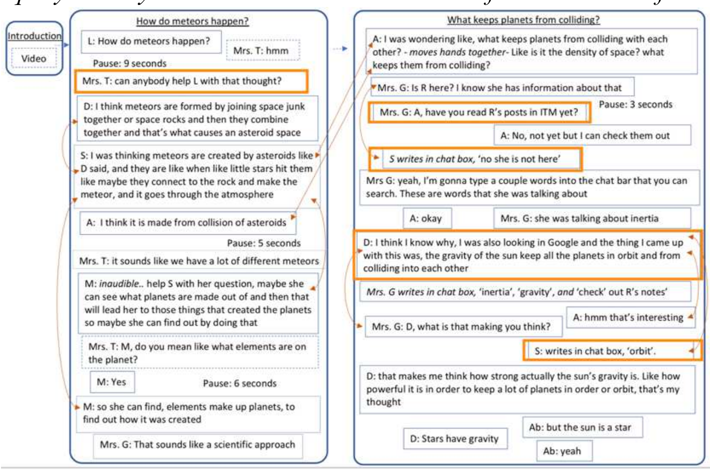


Figure 3
Cross referencing of inquiry activity and relational resources in the first 5 minutes of the meta-cognitive meeting



Discussion and Conclusion

The results suggest that the students were able to carry out active and interactive KB inquiry during the school closures, showing sustained engagement in KB discourse (Table 1). This level of KB work was enabled through the collaborative efforts made by the teachers with their students to reconstruct the learning spaces for personal and collaborative inquiry. The analyses revealed several levels of co-construction. First, the teachers worked with students to reconfigure the material and operational environments in which KB actions and interactions unfolded, such as by adopting Google Meet to host metacognitive meetings. On a deeper level, the community engaged in reflective efforts to revive shared norms and expectations of KB in a new operational environment (e.g. "adding your piece to the puzzle"). The construction/reconstruction of learning spaces was sustained by a learning culture formed around the principles and intentionality of KB (Scardamalia, 2002), which permeated the learning ecology (Barron, 2006; Damsa & Jornet, 2017) via metacognitive meetings and ITM. Earlier in the year, the teachers' and students' embodiment of the KB principles leverage their ownership and agency (Zhang et al. 2011), laying the foundational conditions for collaborative action when faced with unpredicted and challenging circumstances. Ultimately, further co-construction of learning spaces took place as an integral part of the ongoing KB process, through improvisational uses of technology tools (e.g. side talk during Google Meet), creative expansion of inquiry resources, and ongoing cross-referencing between different learning events and resources situated in personal and collaborative inquiry activities taking place online, at home, and virtually. Thus, the teachers and students created dynamic, interactional spaces for KB, replacing some of the critical classroom-based elements, accommodating the limitations they faced (e.g., communication tools), while seizing on new opportunities for students to conduct inquiry in the broader world (e.g., backyard observations and experiencing NASA rocket launches virtually.)

The above findings contribute to an ecological understanding of interconnected learning spaces that are co-constructed by teachers and participants as learning activities unfold. The learning spaces are multifaceted, involving co-framing of the epistemic (inquiry norms and goals), conceptual (ideas situated in activities), social (relational structuring), and material/technological aspects of knowledge practices (Hod et al., 2019). We are conducting more detailed analysis to understand students' agentic input to ongoing inquiry structuring, and the relationality of resources in this process. Further research can also explore if and how agency plays a role in how the students view things in their own home, parental and social support systems, or other spaces they occupy in outside of school, and how the sense of expectancy shapes their participation and connection building, and how objects relate across learning spaces.

Acknowledgements

This research was sponsored by U.S. National Science Foundation (#1441479). We thank our collaborating teachers and students for their creative classroom work enabling this research.

References

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development, 49,*193-224.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design.* Harvard University Press.

Brown, J. S. (2000). Growing up digital: How the web changes work, education, and the ways people learn, Change: T*he Magazine of Higher Learning, 32(*2), 11-20. http: doi.org:10.1080/00091380009601719

Clarke, J., & Dede, C. (2009). Design for scalability: A case study of the river city curriculum. *Journal of Science Education and Technology, 18*(4), 353–365.

Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher, 32*(6), 3-12.

Damsa, C. I., & Jornet, A. (2017). Revisiting learning in higher education—Framing notions redefined through an ecological perspective. *Frontline Learning Research, 4*(4), 39-47.

Damşa, C. I., Nerland, M., & Andreadakis, Z. (2019). An ecological perspective on learner-constructed learning spaces. *British Journal of Educational Technology, 50*(5), 2075–2089.

Engeström, Y. (1987). *Learning by expanding: an activity-theoretical approach to developmental research* Orienta- konsultit.

Goodyear, P. (2020). Design and co-configuration for hybrid learning: Theorising the practices of learning space design. *British Journal of Educational Technology*, *51*(4), 1045–1060.

Green, J. L., & Bridges, S. M. (2018). Interactional ethnography. In: *International Handbook of the Learning Sciences* (1st ed., pp. 475–488). Routledge.

Gutierrez, K. D., & Barton, A. C. (2015). The possibilities and limits of the structure–agency dialectic in advancing science for all. *Journal of Research in Science Teaching*, *52*(4), 574–583.

Hod, Y., Yaari, C., & Eberle, J. (2019), Taking responsibility to support knowledge building: A constructive entanglement of spaces and ideas. *British Journal of Educational Technology, 50*(5) 2129-2143.

Lemke, J. L. (1995). *Textual politics: discourse and social dynamics.* Taylor & Francis.

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind, Culture, and Activity*, *7*(4), 273–290.

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press. Sawyer, R. K. (2015). A call to action: The challenges of creative teaching and learning. *Teachers College Record, 117*(10), 1-34.

Scardamalia, M. (2002) Collective cognitive responsibility for the advancement of knowledge. In: B. Smith (ed.), *Liberal Education in a Knowledge Society*. Open Court

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, *3*(3), 265–283.

Siqin, T., van Aalst, J., & Chu, S. (2015). Fixed group and opportunistic collaboration in a CSCL environment. *International Journal of Computer-Supported Collaborative Learning, 10*(2), 161–181.

Tsui, A. B., & Law, D. Y. (2007). Learning as boundary-crossing in school–university partnership. *Teaching and Teacher Education*, *23*(8), 1289–1301.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Yuan, G., & Zhang, J. (2019). Connecting knowledge spaces: Enabling cross-community knowledge building through boundary objects. *British Journal of Educational Technology*, *50*(5), 2144–2161.

Zhang, J., Hong, H.Y., Scardamalia, M., Toe, C., & Morley, E. (2011). Sustaining knowledge building as a principle-based innovation at an elementary school. *Journal of the Learning Sciences*, *20*(2), 262–307.

Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge building communities. *Journal of the Learning Sciences*, *18*(1), 7–44.

Zhang, J., Tao, D., Chen, M. Sun, Y., Judson, D., & Naqvi, S. (2018). Co-Organizing the Collective Journey of Inquiry with Idea Thread Mapper. *Journal of the Learning Sciences*, *27*(3), 390-430.

