Cross-Boundary Interaction for Sustaining Idea Development and Knowledge Building with Idea Thread Mapper

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Abstract: This study investigated the cross-classroom interaction in four grade 5 knowledge building communities as the third iteration of design-based research. The four classrooms studied human body systems with the support of the Idea Thread Mapper platform. As the students conducted focused inquiry and discourse within their own community, they posted reflective syntheses of their "Journey of Thinking" to a cross-community space accessible to the broader peers from other classrooms. Students from the four classrooms further participated in a live "Super Talk" to collaboratively address a challenging question. Qualitative analyses of classroom videos, online discourse, and classroom observation notes provide a rich description of how the students interacted within and across communities to develop scientific understandings.

Introduction

Educational researchers have made substantial advances to develop collaborative learning environments and support collaborative knowledge building among students (Engle & Conant, 2002; Scardamalia & Bereiter, 2006; Slotta, Suthers, & Roschelle, 2014). Further research is needed to extend collaborative interaction to higher social levels and scales (Stahl, 2013), so students can build on the knowledge of other communities across school years for sustained knowledge building (Zhang, Bogouslavsky & Yuan, 2017). This requires designs for cross-boundary interaction and collaboration, which has gained interests in the broader fields (Star & Griesemer, 1989; Start 2013) but still lacks systematic investigation in the field of computer-supported collaborative learning. The purpose of this design-based research is to test and refine designs of cross-classroom interaction for knowledge building with the support of a new collaborative platform: Idea Thread Mapper (Zhang et al., 2015, Zhang et al., 2018).

Existing explorations of cross-community interactions for knowledge building adopted a single layer interaction design. Each classroom gave other classrooms access to their online discourse space so they could read their notes, respond, and supplement with periodic video conferences (Lai & Law 2006; Laferrière et al., 2012). The findings suggest productive classroom changes. Meanwhile, difficulties arose for students to understand other communities' ideas and discourses without a clear sense of the contexts. New strategies of boundary-crossing support are needed to make knowledge progress accessible across communities.

This research designs cross-community interaction using a multi-level emergent interaction approach, focusing on interactions mediated through boundary objects. "Boundary objects" are artifacts (e.g. reports, tools, models) used to bridge the boundaries (discontinuities) between different social worlds (Star & Griesemer, 1989). Objects from a community often have contextual meanings that are not accessible to other communities. What makes boundary objects effective for bridging different communities of practice is their interpretative flexibility as a "means of translation" (Star & Griesemer, 1989): they have a structure that is common enough to make them recognizable across the different social worlds and allow different communities to interact and work together. Through interacting with shared boundary objects, members from different communities can identify, understand, and reflect on their different practices, leading to enriched understandings within each community and potentially the creation of new, in-between practices (Akkerman & Bakker, 2011).

As noted above, raw distributed online discourse records are hard to use as boundary objects to bridge different knowledge building communities. Therefore, we developed a multi-level emergent interaction approach (Zhang et al., 2017). Students in each community engage in focused inquiry and interactive discourse within their own community's space. As progress is made, students selectively synthesize fruitful threads of inquiry emerged from their discourse. The reflective reviews and syntheses can facilitate peer learning and build-on within each classroom (Zhang et al., 2018); they may further be shared as boundary objects to enable cross-community interaction. Students from other partner classrooms (or a subsequent student cohort) can use the syntheses of idea threads to view into the progress of inquiry and build connections.

We have conducted a multi-year design-based research to test and refine this multi-level, emergent interaction design (Zhang et al., 2017, Yuan, Zhang & Luo, 2018). The earlier iterations/designs were supported by purposeful uses of existing tools offered by Knowledge Forum (Scardamalia & Bereiter, 2006).

On the basis of the findings, we created and upgraded a new collaboration platform: Idea Thread Mapper (ITM) (Zhang et al., 2018), which interoperates with Knowledge Forum. ITM supports knowledge building interaction in a network of "buddy classrooms." Students in each classroom co-organize "juicy" wondering areas (shared inquiry foci) as they pursue interactive discourse to deepen their understandings in a domain area. They compose Journey of Thinking (JoT) syntheses to review progress in each area, focusing on (a) overarching topics and problems, (b) we used to think…now we understand… and (c) deeper research is needed. The wondering areas and syntheses are shared in a cross-classroom space that has an easy search tool. By viewing other classrooms' JoT syntheses, students can get a sense of their inquiry directions and learn from their "big ideas" and deepening questions. As a newly designed feature, ITM allows different classrooms to initiate and participate in live "Super Talk" threads to collaboratively address challenging problems.

This paper reports on a new iteration of this design-based research to refine cross-classroom interaction in a set of four grade 5 classrooms supported by ITM. Our research questions ask: (a) How did students generate JoT syntheses for cross-classroom sharing? (b) How did the four classrooms initiate and pursue "Super Talk" to address challenging problems? And (c) in what ways did the within-classroom discourse and cross-classroom "Super Talk" interact to support deep inquiry and understandings?

Method

Classroom design and contexts

This study was conducted in four grade 5 classrooms (with a total of 89 students who were 10-to-11 years old) that studied human body systems over a six-month period using ITM. The four classrooms, labeled as Class 1-4, were taught by two teachers each teaching two classes. Students in each classroom generated interest-driven questions, co-organized wondering areas focusing on various human body systems, and conducted research using various resources. They conducted reflective knowledge-building conversation (called "metacognitive meetings") in their classroom to build on one another's questions and ideas while reviewing their progress. The conversation continued on ITM in their online discourse space organized as various idea threads each addressing an overarching problem/theme. As progress is made in each idea thread, students co-created and edited JoT to reflect on their knowledge (Figure 1). The JoT was then shared with all the other classrooms. Drawing upon their knowledge built about the various body systems, students in Class 3 proposed a challenging problem for "Super Talk" across the classrooms: How do people grow? (Figure 3). The proposal was supported by the other classrooms. Students from the four classrooms worked together to discuss this overarching question. Near the end of the unit, each class had a metacognitive meeting to review knowledge gained from the "Super Talk" and build connections with the different human body systems.

Data sources and analyses

The data sources included classroom observation notes, video records and transcriptions of classroom conversations, and students' online discourse on ITM and JoT shared in the cross-classroom space. Guided by each of the three research questions, we conducted detailed qualitative analysis of student inquiry process in their home class in connection with student interaction across classrooms. To analyze the quality of students' JoT syntheses, we conducted content analysis (Chi,1997) based on the scientific levels (from pre-scientific to scientific) and complexity of ideas (from unelaborated facts to elaborated explanations) (see coding scheme in Zhang et al., 2007). To understand how the Super Talk took place, we read/re-read our detailed field notes and examined the classroom videos to understand the classroom processes. To understand how the within-classroom discourse and cross-classroom Super Talk interacted to support further inquiry, researchers selectively transcribed two metacognitive meeting videos from each class, one from the 5th month, and the other from the sixth/last month of the inquiry in which students discussed what they had learned from the Super Talk. We analyzed the classroom discussion to trace the formation of cross-topic connections based on the betweenness centrality measure (Oshima, Oshima & Matsuzawa, 2012).

Results

How did students generate syntheses of Journey of Thinking for cross-classroom sharing?

Students engaged in kick-off activities that elicited their interests about the human body in January 2018. Students in each room generated various interests and questions and formulated overarching "wondering areas." These areas became the focus of the subsequent inquiry by individuals and groups using books, online resources, and models. With inquiry progress made in the next two months, students were introduced to the JoT

function in ITM. Focusing on each area of inquiry, students added reflections on their research individually, and then compiled the reflection entries into whole group JoT (Figure 1). The syntheses of JoT were then shared with all the other classrooms in the cross-classroom sharing space.

Figure 1. The Journey of Thinking synthesis written for the area of bones and muscles from Class 1.

To examine the quality of students' reflections in their JoT, researchers coded the ideas summarized under "We used to think" and "We now understand" based on scientific sophistication and epistemic complexity (Zhang et al., 2007) (see Table 1).

Table 1: Coding of ideas in the JoT summarized under "We used to think" and "Now we understand" based on data from the current (2018) and the previous iteration (2017) of this research

	2018		2017	
	We used to think	Now we Understand	We used to think	Now we Understand
Scientific Sophistication				
Pre-scientific	33%	0%	38%	0%
Hybrid	50%	0%	48%	0%
Basic	16.7%	0%	14%	18%
Scientific	0%	100%	0%	82%
Epistemic Complexity				
Unelaborated Facts	83%	%	95%	9%
Elaborated Facts	0%	16.7%	0%	32%
Unelaborated Explanations	16.7%	0%	5%	9%
Elaborated Explanations	0%	83.33%	0%	48%

As Table 1 shows, ideas summarized under "Now we understand" show a higher level of scientific quality and complexity than those summarized under "We used to think." Compared against the data from the previous (2017) iteration of this design-based research in which we tested a similar design without ITM, the ideas summarized under "Now we understand" in the current iteration showed higher levels of scientific and complex quality. A more detailed analysis revealed that the JoT syntheses in 2018 had more words on average than those in 2017 (362.3 versus 170.8 words). These changes suggest the potential improvement made by students in their reflective inquiry with the support of ITM.

How did the four classrooms initiate Super Talk to address challenging problems?

In the beginning of May, at a metacognitive meeting, students in class 3 noticed the new ITM feature of "Super Talk." The teacher explained that this function was for all the classrooms to explore big challenging questions and put their knowledge together. Then Class 3 started to discuss possible challenging questions for Super Talk. Three questions were proposed in total: How are all the systems connected? Which two systems are most connected? And why do people grow? A few students reflected on what they knew about how muscles grow, and several other students showed interests in the growth topic as they had grown a lot during the school year. Then they agreed to focus on one topic for the Super Talk, and decided to have to vote for the one that they felt was most challenging and exciting. The topic of "How do people grow?" was selected. This Super Talk topic was proposed and added in ITM and made visible to other classrooms (Figure 2).
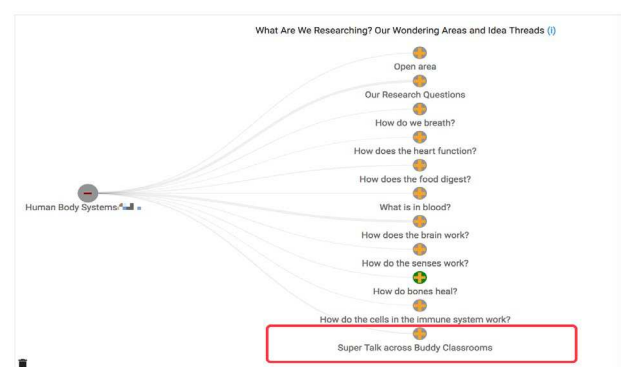

Figure 2. Students' collective wondering areas about human body systems and the Super Talk area.

In the following week, students from Class 3 first started to contribute knowledge about how the brain, bones and muscles grow drawing upon what they had learned about these body systems. The teachers then advertised the "Super Talk" question to the other classrooms. In each case, the teacher read the notes already posted by Class 3, and discussed what might count as a good note for the Super Talk. In the following week, students from the other classrooms started to build on the ideas in the Super Talk (Figure 3).
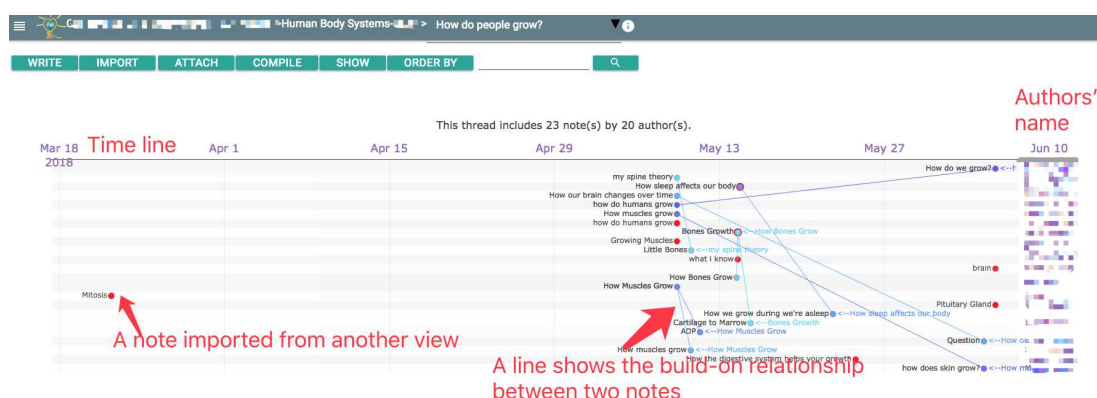

Figure 3. The cross-classroom Super Talk about how people grow. Each dot shows a note, and a line between two dots shows a build-on connection. Each note is positioned based on the date of creation (x-axis) and author (y-axis).

Student A from Class 4, studying the digestive system and energy, found the connection between growth and muscles, so he added more detailed information to the Super Talk. He mentioned that muscles use energy from ATP (Adenosine Triphosphate) for muscle placement. And then Student B from Class 2 built on this idea, saying "Muscles grow by when you stress muscle fibers by lifting heavy weights or doing motions you're not used to, they rip which lets out a chemical called cytokines which activates your immune system which repairs it bigger than it was earlier which makes your muscles grow. Hypertrophy is how your muscles say you need to work more to make your muscles grow." At the same time, a new angle of viewing was presented by Student C from Class 1, who wrote about how sleep affects growth as related to her inquiry of the

brain. Her post highlighted that during the Non-Rapid Eye Movement stage (NREM), the body is actually repairing damaged tissues and growing. New detailed information about bones was further expanded by Student D from Class 2 who was studying bones. He mentioned that "bone grows from cartilage, they fuse together and go through a process called ossification." Later, his peer who studied the same topic built on this note and added more detailed accounts of the process of ossification: "Over time, a different type of cells called osteoclasts head to the middle of the bone to help in. Now, inside osteoclasts there are hydrolytic enzymes and acids. These enzymes and acids will help dissolve the temporarily bone (the cartilage) to make room for the permanent bone (marrow)." Toward the end of the online discussion, Student E from Class 1, who was studying the endocrine system, gave her explanation from the angle of the endocrine system, because the pituitary gland releases a hormone that controls the growth as it plays a huge role in puberty and metabolism. A cross-cutting connection was further built when Student F from Class 2, who was studying cells, found that humans start as cells and all organs are made of cells, and the way cells grow is from mitosis; therefore, cell growth is key to how humans grow. He imported his earlier note about mitosis from his home class discussion into the Super Talk space. This note was read by other students and triggered deeper conversation in other classrooms' face-to-face meetings.

The Super Talk extended till the end of May with a total of 22 students from the four classrooms participating in the discussion. Students collaboratively explained how people grow involving bone and muscles, brain and nervous systems, cells and genetics, and digestive systems. Approximately 50% of the notes are build-ons, reflecting a higher level of collaborative responses. Student notes were coded based on epistemic complexity (Zhang et al., 2007), with 86% of the notes offering elaborated explanations beyond simple facts.

After students shared their Journal of Thinking and participated in the Super Talk collaboration on ITM, each classroom community continued its inquiry activity in June. The teachers named the last mouth as the "Month of Connection," and students extended their learning with the focus on the potential connections between different human body systems. Metacognitive meetings were held to discuss how the different body systems work together, integrating what students had learned from their own inquiry as well as from their peers. As specific body systems and connections were mentioned by students, the teachers took visual notes of the discussion, leading to the co-generation of the concept maps shown in Figure 4.
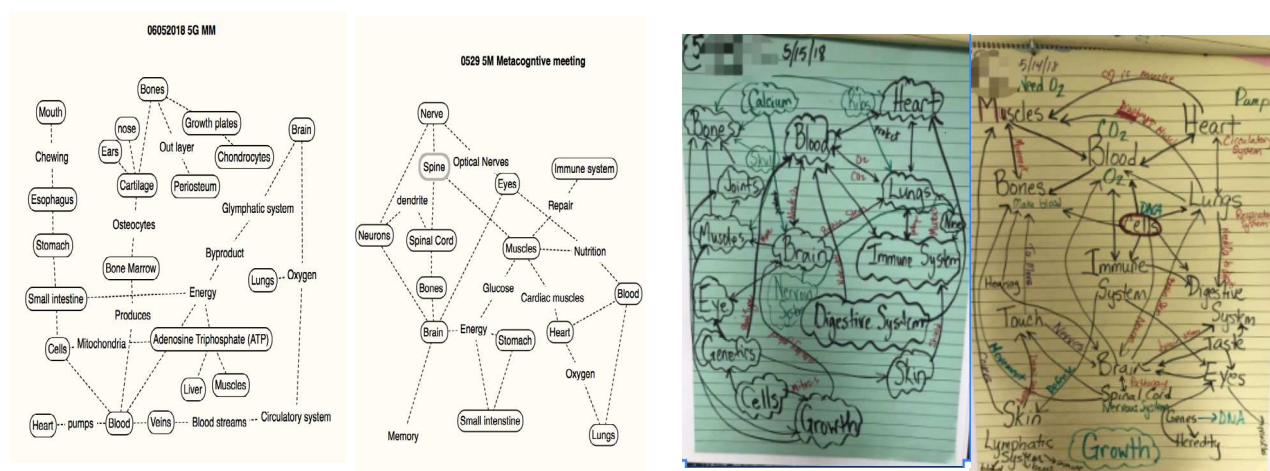

Figure 4. Concept maps of four classrooms metacognitive meetings about connections between human body systems (Class 1, Class 2, Class 3, Class 4, respectively).

During the metacognitive meeting about connections between different human body systems in the 5th month, students made solid reflections, build-ons, and had deep conversations about how different systems connect to each other. As their discourse expanded, students started to understand the concept of the cell as the basic unit of the human body, however, they did not mention the mechanism of cells multiplication. The excerpt below shows how students from Class 3, which was taught by Teacher K, tried to understand collaboratively the cell as the start and basic unit of human body systems and the connections between various systems. Below is an excerpt from Class 3' metacognitive meeting conducted in the 5th month of this inquiry.

K21: I think the cells in the immune system should be connected to cells that fight off the germs to fight cells
K8: Actually the immune system is made up cells.

Teacher K: What else is made up of cells?

K8: Blood

K5: Isn't it everything

K8: Yeah, well everything is made up of cells.

K5: Well there are all different kinds of cells

Teacher K: Ah uh!

K1: Yeah, but everything is made up of cells.

K8: It's the beginning of everything

K5: We could have different specific types of cells, maybe we can go to a bunch of different kinds of cells. Like the brain cells just put it next to the brain?

Teacher K: So basically cells is kind of like there is a reason why I drew it in the center. Is it the beginning of every part? Do we have anybody studying cells?

K12: I know something about cells. oh, it's that, it's my dad told me, we all started out as one little cell and we start to grow.

Teacher K: What? Isn't growth being the big question that we put out up there (on ITM)?

K1: Yeah, so we grow teller just by see cells grow in our body

K5: and then it just multiply, so there are tons of different types of cells. and that's why there are the differences, because there is a different amount of cells of certain types.

K15: I think cells are connected to the growth. because as you grow more cells in your body

Teacher K: Every kind of cells

K15: If you get a lot of cells in your body at one type, that's how we growth spurts I think

Teacher K: I think someone may have some growth expert spurts. Is there anyone want to say the big connections that we are missing?

K10: Gene and heredity

K8: So the immune system is connected to the digestive system, skin, eyes.

Teacher K: Really? Tell us why?

K8: So, it is connected to skin cause skin is actually one huge defense against pathogens.

In what ways did the cross-classroom "Super Talk" leverage deeper discourse in each classroom?

In early June, each class held a face-to-face metacognitive meeting to revisit the question of how people grow. Discourse analysis showed that students brought what they had learned from the "Super Talk" back to their home class discussion and made further connections with the growth of other organs, leading to deepened understandings of the human body systems. Below is an excerpt from Class 3's metacognitive meeting.

Teacher K: Your brain cells are dying? or not making new ones

Student K8: You are not making new ones, but they do start out, they do die as you get older

K5: When you run out of brain cells you die?

K12: *I saw something on ITM about chromosomes, it is kind of related to growth.*

Teacher: What is it, can you reiterate it? What are chromosomes are related to?

K7: Mitosis?

K5: DNA?

Teacher K: Oh, Mitosis? what about DNA? what's that related to?

K5: DNA and RNA.

Teacher K: What is that related to?

K8: RNA is just half of DNA

K12: *Mitosis is the process of one cell splitting into two new cells, it is a complex process of many steps. One prophase. In prophase the structures called centrioles move to opposite ends of the cell and fibers come out of them and enclose the cell. And in metaphase chromosomes line up in the center of*

the cell. Each attaches to two fibers. Chromosome halves pull apart the cell and divide the membrane. Step three is Anaphase and step 4th telophase.

Teacher K: He is talking about really deep science that's behind this (pointing to the drawing) where the one cell is splitting into two equal parts. So when you cut an apple, you know, in the center of the apple gets really cut in half, it really does, that's not the same as what is going on here. With mitosis, it gets cut in half but each half gets exactly the same the central part. Like the same center of the apple grows into both pieces, when it splits apart, and then that's...they split apart to make two identical, and it still has that center of the apple, and what's in the center in the apple, or the center of the cell?

K1: The DNA

K2: Chromosomes

Teacher: DNA and Chromosomes, and what can you tell us about heredity or DNA

K1: Hair color, eye color.

K17: Your genes there are like the blueprint.

To specifically examine the conceptual connections built between different topical concepts, researchers traced co-occurrence of the main domain concepts (e.g. brain, cell, bones, lungs, and heart etc.) in each conversation turn in the two metacognitive meetings mentioned above before and after the "Super Talk." Using the network analysis tool KBDex (Oshima, Oshima & Matsuzawa, 2012), we compared the betweenness centrality of the key concepts, which shows which concepts act as 'bridges' between concepts in a network. Figure 5 shows the changing centrality of each key concept over time in each of the two meetings. Before the "Super Talk", the concept "Brain" stood out as having the highest betweenness centrality among the discussed concepts, suggesting that students' discourse positioned brain as the central topic connected with other systems. In the meeting after the "Super Talk" activity, the concept of "Cell" had the highest gain in betweenness centrality. Student K12, who acted as broker, brought back the concept of cell mitosis from the "Super talk" and triggered extended discussion related to cells in the home class. According to the science standards, the concepts of cell and mitosis are required by Grade 8 and Grade 9-12 respectively.
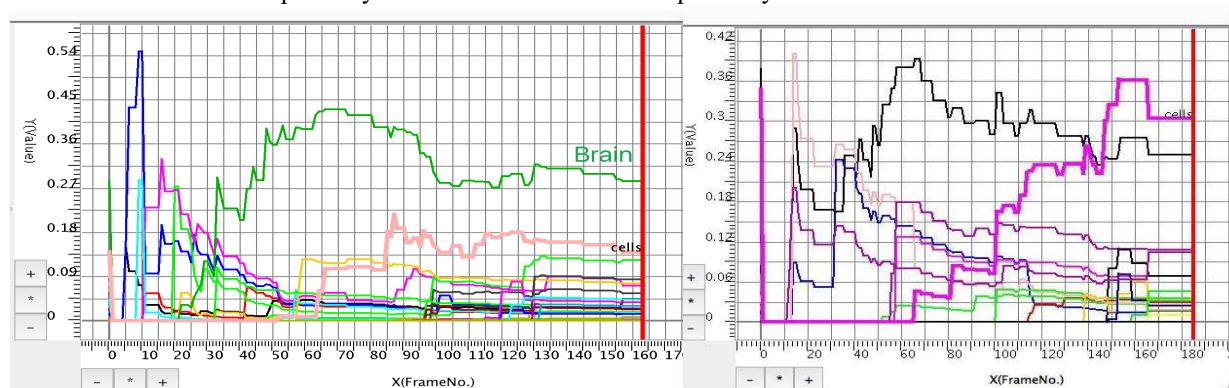

Figure 5. Betweenness centrality of the key concepts discussed in the metacognitive meeting before (Left) and after the "Super Talk" meeting (Right).

Discussion and conclusions

This study tested a multi-level emergence design of cross-community interaction, with students engaging in focused inquiry and discourse within their own classroom while generating reflective JoT syntheses as boundary-crossing objects, and participating in the "Super Talk" to investigate a challenge problem together. The results provided an elaborated account of the processes to generate reflective syntheses and pursue Super Talk. Students showed solid reflections in JoT with the help of ITM compare with last year and students built on knowledge building interactions through the cross-classroom collaboration to extend and enrich the discourse in their home class. More specifically, with collaboration going on in the cross-boundary space, students further expanded their social connections, engaged in addressing challenging research questions and demonstrated higher level collaboration and understanding beyond their classrooms' walls. The cross-community collaboration also enabled students to bring back valuable insights to their home class and triggered further build-on and leveraged the home class' understanding to "rise above" (Scardamalia& Bereiter, 2006). Cross-classroom interactions offer a multi-layer structure which enable the information flow across various sites in a

mutually understanding approach that suggested by Stahl (2013). The analysis of the classroom discourse reveals the benefits of a higher level of interaction enabled by the updated design of ITM as a knowledge infrastructure. Expanding our previous year's work (Zhang et al, 2017. Yuan et al., 2018), the findings shed light on the possible designs and processes to enable collaborative knowledge building across a network of classrooms in a larger learning environment and ongoing learning process. These research results also provide insights that may guide teachers' adoption of cross-classroom collaboration to support student inquiry and extend knowledge building. During the learning process, the teachers played a crucial role in guiding students' cross-classroom collaborations, embracing the ideas from other communities to extend students' thinking, and using child-friendly language to leverage students' understanding, and making connections with other topics in the current classroom.

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