Cross-community collaboration among knowledge building communities

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CROSS-COMMUNITY COLLABORATION AMONG KNOWLEDGE BUILDING COMMUNITIES

By

Guangji Yuan

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ABSTRACT

Cross-community collaboration which expands community members’ interaction to a larger social scale plays a crucial role in increasing information exchange and extending inquiry learning. This dissertation uses a design-based research approach which aims at testing a multi-level emergence design in multiple learning communities. This design serves the urgent need to enable students’ idea sharing and build-on with members from other communities who have similar interests for mutual learning and collective knowledge advances.

A mixed-methods research approach was used to investigate the cross-classroom collaboration over three successive years: pilot 1, study 1, and study 2. Knowledge Building Theory and pedagogy guides in learning and teaching practices. The fifth grade Knowledge Building communities studied human body systems with the support of the Knowledge Forum and the Idea Thread Mapper online platforms. As students conducted focused inquiry and discourse within their own community, they posted their learning reflections to a cross-community space and read other’s learning reflections from both current and previous years. In study 2, the classrooms further participated in an ongoing cross-community discussion in addressing a challenging question.

Findings suggest that the learning reflection takes the form of the Journey of Thinking in this study and enables information transfer among the network of communities. Students wrote and posted their Journey of Thinking to capture substantive idea progress and deepening questions that had emerged from their inquiry. Students showed solid reflections in their Journey of Thinking with the help of Knowledge Forum and Idea Thread Mapper. The multi-level structure allows students’ social interaction in a broader landscape with their peers. Analyses of the classroom conversations elaborated how students built on the insights gained from the cross-
classroom interactions to develop deeper understandings in their home classroom. Analyses of teacher interviews and classroom metacognitive meeting reveal the teachers’ roles to contextualize the purpose of the cross-classroom activities, support Journey of Thinking reading and writing, and scaffold cross-classroom connection and conversation. The results also provided an elaborated account of the ongoing collaboration in the cross-community space.
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# TABLE OF CONTENTS

ABSTRACT ............................................................................................................................ ii

ACKNOWLEDGEMENT .......................................................................................................... iv

TABLE OF CONTENTS ........................................................................................................ vi

LIST OF FIGURES ................................................................................................................ ix

LIST OF TABLES .................................................................................................................. xi

CHAPTER 1 INTRODUCTION ................................................................................................. 1
Background: The Imperative of Knowledge Creation and Cross-boundary Collaboration ...... 1
Statement of Problem .............................................................................................................. 3
Significance of This Study .................................................................................................... 4

CHAPTER 2: LITERATURE REVIEW .................................................................................. 7
Knowledge Building Theory ................................................................................................. 7
Collaborative Responsibility ............................................................................................... 8
Epistemic Agency .................................................................................................................. 10
Knowledge Building Discourse .......................................................................................... 11
Technology and the Online Knowledge Building Environment ........................................... 13
The Role of the Educator in a Knowledge Building Community ......................................... 14
Cross-Community Collaboration with Boundary Objects ....................................................... 16
Boundary Crossing and Boundary Brokers .......................................................................... 17
Obstacles of Boundary Crossing .......................................................................................... 18
Boundary Brokers ................................................................................................................ 21
Boundary Objects ................................................................................................................ 23
Conceputal Framework: Multi-Level Emergence Design of KB Interactions Across Classrooms
.............................................................................................................................................. 27
The generation of boundary objects in the form of the Journey of Thinking ......................... 28
Cross-community interactions using boundary objects .......................................................... 29
Research Goals ................................................................................................................... 31

CHAPTER 3 METHODOLOGY AND OVERVIEW ............................................................. 33
Research Overview ............................................................................................................. 33

CHAPTER 4 PILOT STUDY ................................................................................................. 35
Classroom Context and Design ........................................................................................... 35
Future Research Directions......................................................................................................... 103
References................................................................................................................................... 104
LIST OF FIGURES

Figure 1. The Journey of Thinking Created by Blood and Cells Group in study-1 using the Journey of Thinking scaffolds: Our research topic and problems, we used to think, now we understand, we need deeper research. ........................................................................................................ 29

Figure 2: The visualization of the multi-level emergence design of KB Interactions across classrooms conceptual framework ........................................................................................................ 31

Figure 3. Journey of Thinking Created by the Two Classrooms in Relation to Regular Knowledge Forum Notes. ............................................................................................................. 38

Figure 4. During the metacognitive meeting, students sit on the rug and share their learning, build-on each other’s ideas, and advance the community’s knowledge together. ........................ 44

Figure 5. The Inquiry cycles and Knowledge Building roles posters that hang on the classroom wall ................................................................................................................................................ 44

Figure 6. Students created their first wondering areas based on the similarity of their initial research questions. ........................................................................................................................ 47

Figure 7. Knowledge Forum local group working Interface ................................................................................................................................. 48

Figure 8. A set of Journey of Thinking were selected and posted in students “super view” for them to read as supportive reading materials ............................................................................... 49

Figure 9. The “Super View” with both previous year’s notes and current year’s Journey of Thinking ........................................................................................................................................ 50

Figure 10. The number of Journey of Thinking created by classroom K, M, G, and W over time. ....................................................................................................................................................... 58

Figure 11. The topic distribution of the Journey of Thinking created by the four classrooms. ... 59

Figure 12. Topic distribution of students’ regular notes posted in their local online discourse... 59

Figure 13. Social network analysis of who had read whose Journey of Thinking among the students from the four classrooms. Each node denotes a student. A line linking two students shows a social tie created through the read. .................................................................................. 63

Figure 14. Social network analysis of cross-year Journey of Thinking reading (blue represents the current four classrooms’ Journey of Thinking, red represents the previous years’ Journey of Thinking) ....................................................................................................................... 64

Figure 15. During the metacognitive meeting, students sit in the rug and share their learning, build-on each others’ ideas, and advance the community’s knowledge together ......................... 73

Figure 16. Students were eating apples and writing down their initial thoughts and inquiries of the digestive systems in the beginning of the unit during kick-off activities. .............................. 75

Figure 17. Students generated their inquiry questions and formed initial wondering areas in the beginning of the unit. ........................................................................................................................................ 76
Figure 18. Example of students wondering areas on ITM in the beginning of the learning unit (Left) and the wondering added at the end of the unit (Right) ................................................................. 77

Figure 19. An example of students ITM wondering area, the red notes stand for each thread, the line stand for the function of “build-on” notes. ............................................................................................. 77

Figure 20. In each wondering area, there is a Journey of Thinking function. After students accumulated numerous information in their area, they can start to write their group Journey of Thinking....................................................................................................................................... 78

Figure 21. The “Show wondering Areas and Idea threads” function in the cross-community space enables students to have a bird’s eye view of other communities’ wondering areas. By clicking each round blue icon above the title, it will link to the focal page. ................................................................. 79

Figure 22. The keyword function in the cross-community space enables students to find the relative Journey of Thinking synthesis quickly, the keywords are also highlighted in the context. ........................................................................................................................................ 80

Figure 23. The Journey of Thinking synthesis written for the area of bones and muscles from Class 1 with ITM. .......................................................................................................................................................... 86

Figure 24. Students’ collective wondering areas about human body systems and the Super Talk area. .......................................................................................................................................................... 88

Figure 25. 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). ................................................................. 89

Figure 26. Concept Maps of four classrooms metacognitive meetings about connections between human body systems (Class 1, Class 2, Class 3, Class 4, respectively). ......................................................... 91

Figure 27. Betweenness centrality of the key concepts discussed in the metacognitive meeting before (Above) and after the “Super Talk” meeting (Below). ................................................................. 94

Figure 28. After the teacher guided students’ reading on ITM notes, students from the digestive system group brought an experiment chemical and mechanical digestion, to share in their metacognitive meetings ........................................................................................................................................ 95

Figure 29. Blood group students are sharing their experiments with the topic of blood types, they wrote down their key scenic words and hang on an easel before the metacognitive meeting...... 96
LIST OF TABLES

Table 1. Coding of Ideas in the Journey of Thinking Summarized under “We Used to Think” and “Now We Understand.” .................................................................................................................. 60
Table 2. Coding of questions in “Journey of Thinking,” including questions explored and those for further research........................................................................................................... 61
Table 3. Students’ perspectives of the Journey of Thinking based on interviews.......................... 62
Table 4. How Students work with Other Grade 5 Classrooms’ Journey of Thinking...................... 65
Table 5. Excerpt of one metacognitive meeting about Journey of Thinking in the Super View... 66
Table 6. Comparison of coding of ideas in the Journey of Thinking summarized under “We used to think” and “Now we understand.” between 2017 and 2018.................................................. 87
Table 7. Excerpt of Teacher’s role in a metacognitive meeting .................................................. 97
CHAPTER 1 INTRODUCTION

Background: The Imperative of Knowledge Creation and Cross-boundary Collaboration

As societies have entered the Knowledge Era, the new generations are facing new opportunities as well as unprecedented challenges, such as environmental pollution, climate change, cultural conflicts, cybersecurity, social and ethical issues associated with genetic discovery and so forth. Creative ideas and new ways of idea creation are needed to tackle these important issues. “Innovation is becoming recognized as not just a priority for individual organizations but as an imperative for whole nations and regions” (Bereiter, 2014, p. 62). Over the last few decades, governments have been providing resources to support research projects and innovation centers; however, the core of innovativeness still depends on the people in each field to make efforts to make creative advancement of knowledge. Thus, school is a major base to supply qualified students and civil citizens, carrying the responsibility to equip students with creativity as one of the essential cognitive skills. However, there is a challenge to improve the human capacity for innovation through child-rearing, the cultural environment, and the education system.

The time-honored fallback from earliest times in pedagogical research is “learning by doing”, which reflects how we learn most of our everyday skills and knowledge (Dewey, 1938). It is important to recognize that working with ideas is also learning by doing. “New social and technological environments will play an essential role, but the focus must be on supporting sustained creative work with ideas and supporting it so effectively that collaborative knowledge-building interactions become the norm for educational engagement” (Bereiter, 2014, p. 63). This new norm includes students in the core together with teachers and schools, and advocates students as the driving force, as they are the ones who need to generate ideas and steer their
future with sustained creative work. To cultivate innovation and collaboration, students need experiences such as scientists have in real life (Bereiter, 2014). This requires schools to immerse students in a sustained inquiry and self-directed learning environment, and cultivate students who can deal with idea complexity and creativity (Scardamalia & Bereiter, 2006, Zhang, Bogouslavsky & Yuan, 2017).

As the research progresses, cross-discipline and trans-disciplinary research is emerging, transforming the research field and bringing new opportunities and promising results. New research methodologies have emerged, focusing on research teams or individuals integrating information, data, techniques, tools, and/or theories from two or more bodies of specialized knowledge to advance fundamental understanding, and have evolved into interdisciplinary and cross-boundary research that can solve thorny problems beyond their own single discipline or research field. Technology has made industries more globally connected, allowing organizations to fuse forces across geographies, industries, and professions. This is especially true for recent innovation projects, where experts from various field bring their specialized knowledge into play. With global operations, complex work requires people to collaborate to get things done outside of the context of a formal area. But there’s a hitch: these new forms of cross-boundary collaboration and connection are not adequately represented in the field of education, especially in computer-supported learning. Research on collaborative inquiry and Knowledge Building in schools needs to address the challenge of how to enable cross-classroom interactions for sustained Knowledge Building. To cultivate deep and creative knowledge practices, schools need to engage students in authentic inquiry and collaboration with effective support. Beyond short and scattered inquiry activities, it is important to enable a progressive, collective trajectory of
inquiry sustained over a long term for productive effects (Dean & Kuhn, 2007; Engle, 2006; Hakkarainen, 2003; Zhang et al., 2015).

**Statement of Problem**

One critical capability people need in the 21st century is knowledge creation ability (Scardamalia & Bereiter, 2006). Yet in many institutions, cultivating knowledge creation has been misconstrued as a skill that can be achieved in the short-term. Although many people anchor their hope in school, they neglect the fact that hitherto schools have dealt with knowledge in very different ways from the real world. It is common in education to treat ideas as what people believe or should believe, expecting students to respond to these ideas with agreement or disagreement or show evidence to prove their points of view. Such culture of learning increasingly reveals disjoints with knowledge creation work in the real world that mainly emphasizes the usefulness, adequacy, improvability and developmental potential of ideas (Bereiter & Scardamalia, 2003). Rarely does educational research focus on longitudinal discourse beyond short and scattered inquiry activities (Laferrière et al., 2012; Lai & Law, 2006). In order to support these necessities, more schools should adopt inquiry-based learning and strengthen the collaboration between different groups and communities. A creative field leverages the work of all communities and their members by accumulating a shared and accessible knowledge base, represented using various inscription systems, facilitating dynamic contraction, and cross-fertilization of ideas (Csikszentmihalyi, 1999). We face a major challenge in how students can engage in a sustained inquiry trajectory through coherent authentic practices, how to transform current science classrooms into knowledge creation communities, and how to sustain such authentic inquiry across classrooms.
Pioneer researchers in the field of inquiry-based learning have made progress in understanding how these needs may be addressed in educational institutions. For instance, *Learn by Design* (Holbrook and Kolodner, 2000) stresses science learning as it is achieved through addressing a major design challenge by developing and refining their designs; *Project-Based Science* focuses on “student-designed inquiry that is organized by investigations to answer driving questions and includes collaboration among learners and others.” (Marx, Blumenfeld, Krajcik, & Soloway, 1997, p. 341) *Problem-based Learning* focuses on teaching medical knowledge and skills to medical school students by engaging them in solving problems similar to those they will encounter later in medical practice (Barrows, 1996). Research on inquiry-based pedagogies have made progress in understanding how current educational needs may be addressed, and Knowledge Building pedagogy encourages students to take up their collaborative responsibility to expand the community’s knowledge at stake and knowledge build-on (Bereiter & Scardamalia, 1989; Scardamalia, 2002). However, important research gaps persist.

Existing studies have mainly focused on the inquiry discourse for individual classrooms, and the discourse mainly focuses on the single community level. However, research gaps persist in how students extend their interaction with other communities to sustain and build-on their authentic inquiries over a long period of time; more studies are required to understand the nature of boundary objects and how to facilitate boundary crossing learning processes for knowledge creation over time. This study attempts to address these research issues.

**Significance of This Study**

This research study is a design-based research study aimed at testing multi-level emergence design of cross-community interactions in Knowledge Building communities. It serves to address the urgent need to enable students’ idea sharing and build-on with members
from other communities who have similar interests for mutual learning and collective knowledge advances. The significance of this study is first investigating how technology facilitates students’ reflection of their best knowledge and collaboration across boundaries in Knowledge Building communities. Guided by Knowledge Building theory and pedagogy (Scardamalia & Bereiter, 2006; Scardamalia & Bereiter, 2010) and boundary crossing framework (Star & Griesemer, 1989), the cross-classroom interactions are supported by a newly designed tool, Idea Thread Mapper (ITM) (Zhang, et al. 2015).

The significance of this study is also in its attempt to fulfill the urgent request for understanding how to conduct cross-boundary learning with boundary objects in a multi-layer research design study. A greater demand for elementary students with a strong science background justifies the need for more efficient, effective, life-changing learning approaches with computer-supported online collaborations. Schools and classrooms that implement new designs of cross-classroom learning with boundary objects in Knowledge Building communities driven by the results of this study will be better able to train students and inform teacher practices.

As for teachers, this study will help them uncover critical processes of boundary object generation and cross-classroom sharing processes. In order to have a clearer understanding of how to conduct cross-classroom interactions and be involved in this continuous process, this study provides practical examples in various stages. Teaching in multi-level KB environment requires teachers to work with more complex and diverse communities and see cross-classroom interaction as methods of learning while supporting the process. This study elaborated the detailed teachers’ roles to offer potential guidance for future use and modification. For researchers, this study will unveil the nature of the boundary objects and students’ perspectives
of boundary objects and the hidden social interaction patterns which previous studies have rarely seen.
CHAPTER 2: LITERATURE REVIEW

Knowledge Building Theory

Having students equipped with knowledge creation skill is very important to prepare them to meet the new challenges in the knowledge era. Bereiter and Scardamalia (2003) proposed a promising way for schools to cultivate knowledge creation ability to immerse students in natural knowledge creative environments and intentional learning settings. Knowledge Building (KB) theory and pedagogy aim to address the urgent needs of cultivating knowledge creation communities to support knowledge creation in schools based on decades of research on expertise and knowledge transforming processes (Bereiter & Scardamalia, 1987; Chen & Hong, 2016). KB is defined as the production of knowledge that adds value to the community with goals to facilitate forms of engagement that drive knowledge creation (Bereiter & Scardamalia, 2010; Scardamalia & Bereiter, 2006). As a nascent pedagogical approach, KB Theory is also described by Bereiter and Scardamalia as “productive work that advances the frontiers of knowledge as these are perceived by a community.” (2003, p.1370). At the same time, KB emphasizes students’ knowledge-creating processes and advocates that knowledge is the outcome of a process of collaborative construction (Bereiter & Scardamalia, 1993). KB calls attention to the complex dynamics of science inquiry and treats idea creation as having a public life since the process of creating cognitive artifacts and synthesizing of ideas takes place through group discussions.

Knowledge Building theory supports the development and creation of idea trajectory extended over time. KB has been characterized as a metaphor of “knowledge-creation” which concentrates on “mediated processes where common objects of activity are developed collaboratively.” (Paavola and Hakkarainen, 2005, p.535) However, KB is slightly distinguished
from this metaphor as it also has a long-term feature in education which emphasizes students’ knowledge acquisition and “provides them with a knowledge base and conceptual tools for further Knowledge Building” (Bereiter & Scardamalia, 2014, p. 47). Empirical studies have demonstrated that KB can facilitate students’ deep understanding in various education regimes, grade levels and cultural backgrounds (Chen & Zhang, 2016; Gan. et al, 2010; Moss & Beatty, 2010). However, previous studies mainly focused on Knowledge Building activities within one single community. How do students collaboratively attribute their knowledge to the community to support idea development within their own community? Further understandings are needed in how students engage in cross-community activities in Knowledge Building learning environments. Thus this proposal investigates students’ cross-classroom activities from three Knowledge Building principles: collaborative responsibility, epistemic agency and Knowledge Building discourse.

Collaborative Responsibility

Collaborative responsibility is critical in developing and expanding the overall knowledge frontier of the community. It is defined as “the condition in which responsibility for the success of a group effort is distributed across all the members rather than being concentrated in the leader” (Scardamalia, 2002, p. 2). Collective responsibility for community knowledge reflects “the commitment of team members to community goals and the willingness to take responsibility for advancing the collective state of knowledge. Team members are committed to contributing knowledge for public good. They understand that expertise is distributed within and between communities, and see themselves as part of a civilization-wide effort to advance the frontiers of knowledge” (Bereiter & Scardamalia, 2017, p. 402). This means that each member in the KB community should not only notice what they have contributed but recognize what is
needed for the group’s success at a higher level in the community (Bereiter & Scardamalia, 2010). There are diverse ways for members to take collaborative cognitive responsibilities in participating as contributors, for instance, contributing ideas, keeping learning enthusiasm, and showing pleasure in accomplishments (Resendes, 2013). More importantly, students’ responsibility is not only for their own success in meeting learning objectives but also for managing the long-term course of inquiry and collaboration (Scardamalia & Bereiter, 1991; Scardamalia & Bereiter, 2010). In empirical studies, researchers have found that students can take collective cognitive responsibilities for KB by various forms. For example, Hmelo-Silver and Barrows (2008) found that students took responsibility for asking high-level questions and building on one another’s thinking to collaboratively refine explanations. Zhang et al (2009) show that students’ collective responsibility can be increased through an opportunistic-collaboration environment that goes beyond fixed small groups, contributing to productive knowledge advances. Hong, Chang and Chai (2014) conducted a study of 30 college students who took a living technology course in a KB setting. Results showed that students are able to work more collaboratively and productively with ideas, as they consistently generate new notes, build on the work of others, and add keywords to the enrichment and deepening of their ideas collectively. Furthermore, the study showed that students become more collaborative when constructing collective knowledge online over time. Similarly, Phillip’s (2011) research found that students developed both their reading and writing network more rapidly during the mid-term instead of the beginning as these two networks are shown to be highly connected over time. Zhao and Chen (2014) conducted a quasi-experimental study based on 102 year-one international business class students. Results indicated that due to students engaging in more collective meta-discourse, KB groups achieved higher scores on beliefs about collaboration and
gained higher academic literacy than the comparison project-based learning groups. These empirical studies indicate that KB can significantly promote students’ collaboration in an online environment, and students can benefit from the co-construction of knowledge. However, those studies all focused on students collectively taking responsibility in supporting the knowledge creation within their own community and not in cross-classroom interaction. Thus how students participate and contribute in cross-classroom activities remains unknown.

**Epistemic Agency**

To take over a higher level of epistemic agency, students should identify their learning needs and pursue learning in their zone of proximal development (Vygotsky, 1987). However, teachers may doubt children have this ability in learning. Traditionally, teachers have preferred to use a task-based model where students are minimally involved in cognitive processes (Thomas & Sandhu, 1994; Ellis, 2003), or to use a knowledge-based model where students are involved in cognitive processes but not taking a higher level control of their learning process (Murray, 1998). Teachers, education theorists and policy makers in education must give serious consideration to the transfer of epistemic responsibility from teachers to students and cultivate students’ inquiry and research capability (Bereiter & Scardamalia, 2014). A KB community is designed to sustain students’ energetic learning impulses by taking over a higher level of agency (Bereiter & Scardamalia, 1989, Hakkaraine, Paavola, Kangas & Seitamaa-Hakkarainen, 2013, Scardamalia & Bereiter, 1991). It requires participants to recognize both a personal and collective responsibility for the success of KB (Scardamalia, 2002). Individually, students make decisions for their focal inquiry, and collectively “they deal with problems of goals, motivation, evaluation, and long-range planning that are usually left to teachers or managers” (Scardamalia, & Bereiter, 2010, p. 10). Thus, students need to choose what research topic they want to learn, at
what time, and working with whom in a sustained learning trajectory (Scardamalia & Bereiter, 1991). When students function as epistemic agents, they also need to reflect on whether they are on the right track, monitor their learning progress, recognize dead ends, compare different resources to support their explanation, and so forth (Scardamalia, 2002). Students’ ability to judge the potential promise of community ideas can play a significant role in supporting their agency for knowledge advancement. Chen, Scardamalia and Bereiter (2015) examined how grade 3 students continually exercise epistemic agency in making decisions and selecting promising ideas under conditions of uncertainty about learning outcomes by using a Promising Ideas Tool. The results show that students become self-sufficient and creative thinkers, and they can make promising judgements that are a benefit to their community and enrich the KB discourse. However, the potential promise of a community’s ideas usually ends after the project is done. The discourse of Knowledge Building usually ceases within one community and cannot be accessed by other communities to extend the value of ideas that have been generated. A newly designed project is needed to enable the ideas and Knowledge Building discourse to be extended beyond its own community, continually making connections and facilitating knowledge build-on among different classrooms over time through Knowledge Building discourse.

Knowledge Building Discourse

Productive collaborative Knowledge Building discourse depends on whether the dialogue leads toward the progress of a knowledge objective (Bereiter, Scardamalia, Cassells & Hewitt, 1997). This is because epistemologically, KB theory considers knowledge as “intellectual property” and the “state of the art” where knowledge has its own life, instead of being possessed by any specific individuals or groups or documents (Bereiter & Scardamalia, 2014; Popper, 1972). “Knowledge-building discourse requires going beyond sharing ideas and
expressing opinions to draw distinctions, refining models and artifacts, and formulating increasingly higher level problems and solutions to capitalize on the strengths and overcome the weakness of competing ideas” (Bereiter & Scardamalia, 2017, p.402). Hmelo-Silver and Barrow (2008) explain that knowledge-building discourse is “building a deep understanding of a problem, questions that promote deep thinking, and continual efforts to refine and improve ideas” (p. 9). They found that the KB learning group worked progressively to develop their ideas through active engagement in knowledge-building discourse. Thus, the dialogue in KB is inclined to dialogue that contains collaborative knowledge creation features. It is not natural or easy for individuals to sustain knowledge-building dialogue since knowledge creation discourse evolves in face-to-face idea-centered group discussion, online work with writing notes, and other related actions to mindfully determine the gap of knowledge assets in the community. To support this process, many researchers have developed online tools to facilitate Knowledge Building discourse. For instance, Oshima and colleagues applied Social Network Analysis by using Kb DeX for in-depth discourse analysis, which provides new visualization support of social knowledge advancement in a KB environment (Oshima, Oshima & Matsuzawa, 2012). By analyzing datasets of deep qualitative discussions, they found that the pivotal point in students’ KB discourse can actually support social knowledge advancement. Researchers also discovered that by using two forms of group-level feedback to support students’ metadiscourse -- visualization of vocabulary tool word-cloud and discourse pattern reflection of scaffold usage -- the group who used these two feedback tools revealed more knowledge in domain-specific vocabularies and showed stronger interpersonal connectedness of online discourse (Resendes et al., 2015). As the emergence of big ideas and deep principles is through progressive refinement across the network of participants. They bring distributed expertise to the challenge, linking
views and notes in new ways and encouraging lateral, cross-boundary thinking” (Bereiter, Scardamalia, 2017, 403). However, current studies mainly focus on the Knowledge Building discourse within each individual community; limited study has been done on Knowledge Building discourse beyond or across communities.

**Technology and the Online Knowledge Building Environment**

To support collective Knowledge Building in an online environment, Computer-Supported Intentional Learning Environment (CSILE) was invented (Bereiter & Scardamalia, 1989), which later evolved into Knowledge Forum® (Scardamalia, 2004). Knowledge Forum offers an online Knowledge Building space for students to carry cognitive actions, archiving students’ ideas, enabling collaborative work, and supporting progressive KB discourse beyond face-to-face settings (Bereiter & Scardamalia, 2003; Chen & Zhang, 2016). More specifically, it provides a public space where students can take their higher epistemic agency to create notes, build on other’s notes and criticisms synchronously and asynchronously to improve the outcome of a community’s knowledge (Scardamalia, 2002). As “the essence of creative work with ideas is making connections” (Bereiter & Scardamalia, 2003, p.19), graphical layouts of notes and connected links can track the change of growing texts, and the collection of the notes stands for the summary of collective understanding of the community (Chen, Scardamalia & Bereiter, 2015). With the support of embedded epistemic scaffolds, for instance, “my theory”; “I need to do further research” reducing students’ cognitive load and identifying discourse moves (Resendes et al, 2015), these epistemic markers are customized to students to support idea-centered activities such as theory building, information sharing and cognitive reflections (Bereiter & Scardamalia, 2014).
In addition to this main platform, there are other technology tools that support students’ reflective noticing, adaptive structuring, facilitate the efficiency of community collaboration, and support selecting promising ideas in the community. For instance, Analytic Toolkit (ATK; Burtis, 1998) provides summary statistics on knowledge forum database activities for individuals and community level analysis. Knowledge Building Discourse Software (Oshima et al., 2012) which is applied social network analysis patterns in analyzing students’ word patterns and lexical patterns. Promising Ideas Tool supports students in identifying promising ideas in KB (Chen et. al., 2015). Van Aalst and his team (2012) developed Knowledge Connection Analyzer, which enables students to reflect on their online work in KF. These tools have shown a promising and effective ways to support students’ collaboration and idea sharing with in one community. However, a new function or a new tool is needed to further support the progress of students’ inquiries and collaboration across communities and over time. To meet these new practical urgent needs. Zhang and colleagues (2015) invented a software called Idea Thread Mapper (ITM), which supports students’ reflective thinking and facilitate the emergence of collective structures of students’ inquiry, and enables cross-community collaborations (Zhang et al, 2015). In this study, I used ITM to investigate students’ collaborations and discourse patterns while they do cross-community activities.

The Role of the Educator in a Knowledge Building Community

The teacher’s role in KB is a facilitator and a co-learner instead of an information provider, a guide instead of a director. Teachers in KB allow students to take over a higher level of agency, and they are also engaging in reflective noticing of the overall learning processes and making open-ended planning, questioning, co-planning the areas that need further improvement, and creating a safe and free environment for students to share their ideas (Hmelo-Silver &
Barrow, 2008). As Chai and Lim (2011) point out, it is crucial to encourage teachers to work on ideas and cognitive artifacts, as they are the key to classroom transformation, and teachers should have first-hand experience with idea-improvement in a collaborative environment (see also Hong et al. 2014). The teacher’s role is nonetheless important in a collaborative learning environment, and in fact has an enhanced role in KB since the teacher takes more responsibilities than in traditional learning. Because in a traditional class, teachers often use one single criterion to evaluate all students’ learning ability, it is the teacher’s job to transmit knowledge to students, but they tend to ignore how students conceive this knowledge and whether or not they build a meaningful construct from it. However, in KB, during the learning experience the teacher treats each student as an individual unit by closely observing each student’s understanding and requirements and identifying possible future learning directions. Teachers facilitate Knowledge Building through asking open-ended metacognitive questions, not making evaluative comments, pushing students to explain their thinking, and problematizing students’ ideas to help support this progressive knowledge-building discourse. According to a recent empirical study investigating teachers’ professional identity in KB, Vokatis and Zhang (2016) identified that teachers in KB have five distinctive identities including: professional knowledge builders, co-learners forming symmetrical relationships with students, problem-solvers and barrier-breakers, and members of a professional community that encourages collaboration and innovation. It is argued that teachers who are more experienced in collaborative KB settings are more capable of facilitating the school’s transformation into a knowledge creation organization (Hong & Scardamalia, 2014). A further international collaboration among teachers provides strong support for those seeking help to implement technology-supported Knowledge Building in their classrooms (Laferriere, 2012). Due to the important role of teachers in the traditional KB learning environment, it is crucial to
study how teachers are involved in and facilitate the cross-classroom collaboration. However, current studies lack evidence and investigation in the teacher’s role in cross-classroom interactions.

**Cross-Community Collaboration with Boundary Objects**

Boundaries exist between communities, ideas, identities, structures, institutions, and other entities. The nature of a boundary is ambiguous and complex. Star and Griesemer assert that “the boundary nature is reflected by the fact that they are simultaneously concrete and abstract, specific and general, conventionalized and customized (1989, p. 406). Akkerman & Bakker (2011) also illustrate that boundaries “have an ambiguous nature in that they are both-and as well as neither-nor phenomena at the same time” (p. 150). The complexity and ambiguity of boundaries make them full of potential from which emerges new possibilities and potential learning opportunities. What characteristics and difficulties do boundaries entail in learning and knowledge transfer? Researchers have studied the characteristics of boundaries from the premise of “knowledge in practice”. A boundary can be considered as “localized, embedded, and invested within a function” (Carlile, 2002, p. 442). Thus working across functions often results in generating problematic knowledge boundaries. The researcher investigates three major boundaries in knowledge sharing across occupational and professional groups at the syntactic (i.e., accurate communication between two sites across a boundary), semantic (i.e., even if a common syntax exists, the interpretations are different), and pragmatic (difference in practice) levels. By studying how knowledge is structured differently across the four primary functions that are dependent on each other in the creation and production of a product innovation process (sales-market, design engineering, manufacturing engineering, and production), the researcher highlights the pragmatic boundaries that are most difficult to overcome as they necessitate the
development of new practices and organizational change (Carlile, 2002). The reason can be explained by Bourdieu’s relational structuralism which points out that after people accumulate their knowledge that is “at stake”, they are reluctant to change their hard-won knowledge because the change of their knowledge and skill is costly (Bourdieu and Wacquant 1992). Thus the author asserts that despite cross-boundary challenges from the difficulty of communication, individuals should actively resolve the negative consequences from practice, and be willing and able to influence and transform the knowledge used by the other functions. These findings shed light on what difficulties students might encounter during cross-community activities. However, it is still unclear in the Knowledge Building environment how students react and handle these difficulties when they encounter boundaries and how students learn from the boundary crossing experiences.

**Boundary Crossing and Boundary Brokers**

Boundary crossing is a challenging and little-studied category of cognitive processes. It can be considered as a person’s transition and interaction across different sites (Akkerman & Bakker, 2011), which means boundary crossing entails stepping into unfamiliar domains (Suchman, 1994). Boundary crossing facilitates extension of knowledge inquiry among different knowledge sites and benefits the growth of the whole community’s progress. It enables students to take collaborative responsibilities and sustain knowledge build-on over time, and it allows newcomers to have the privilege to learn from existing knowledge that was co-created by the previous years’ students (Zhang, 2017).

Boundary crossing moreover provides an opportunity to continue the inquiry and contribute new knowledge assets. It is essentially a creative endeavor which requires new conceptual recourse. Previous studies of creativity and innovation between boundaries focus on
“the potential opportunity of transporting ideas, concepts and instruments from seemingly unrelated domains into the domain of focal inquiry” (Engestrom, 1995). To further understand the mechanisms of boundary crossing, Akkerman and Bakker (2011) analyzed the literature and found four major learning mechanisms that constitute the learning potential of boundary crossing including progresses as: Identification, Coordination, Reflection and Transformation. Those findings revealed that boundary-crossing requires participants to be cognitively involved in the process.

Boundary crossing happens not only between groups from the same scale; sometimes it involves interactions between multiple scales (Stahl, 2013). Sawyer’s (2005) social emergence theory conceptualizes the interactions and processes at different levels as forms of “collaborative emergence” (p.36). Boundary crossing carries learning potential in dialogical phenomena; it requires both continuity and discontinuity in two or more sites that are relevant to one another in a particular way and significant cognitive retooling (Akkerman & Bakker, 2011).

Obstacles of Boundary Crossing

On one hand, boundary crossing contains learning opportunities. On the other hand, there are many obstacles during boundary crossing. Boundary crossing processes may be hindered in both cognitive inertia (for example, when the members’ strivings for unanimity override their motivation to realistically appraise alternative course of action, Janis, 1983, p. 9) and fragmentation (lack of “shared mental models’ among a community of practitioners). Thus it is important for participants to take up their higher level of agency to actively engage in the boundary crossing activities with a clear/shared goal in mind.

In order to further understand the mechanism behind boundary crossing, Engestrom (1995) captured the important interactive process and mediating artifacts involved in boundary
crossing in specific cultural-historical activity systems. One example that the author used was two groups of teacher-formed teams, aimed at planning and executing the local curriculum in a collaborative way. A joint meeting of two teacher teams formed a boundary crossing. However, it did not lead to a shared concept of action plan between the two teams. On the contrary, it sharpened the differences between the views held by the two teams. Thus, the authors argued that argumentation is not fruitful if there is no common point of reference. However, their practice of dividing the students into groups enabled the two teams to compare and contrast their views which led to a comparison between theoretical principles and practical implementation in a creative concept formation. This example illustrates that boundary crossing does not have to reach mutual agreement upon interpretations across boundaries to be fruitful. Moreover, the realization of differences by argument in two teams may trigger important collective concept formation on both sides. Thus, to overcome such a deficiency, boundary crossing requires the formation of new mediating concepts which may be analyzed as a process of collective concept formation.

To further understand these challenges in boundary crossing process, Novak (2007) identifies three types of barriers in cross-community exchange: 1) \textit{Through worlds and interpretive schemas} which notes that knowledge can have different meanings in different communities, and the meaning of concepts and the usage of them is largely context dependent. The same concept may be used in different ways; 2) \textit{Low intensity of direct communication and lack of externalization}. Novak asserts that socialization needs extensive interaction and information communication, whereas, internalization requires community discourse and information exchange. However, because members’ communication and interaction of different communities are narrow and rare, socialization can’t happen. What’s more, the lack of a
continuously shared domain of interests prohibits members’ motivation and resources for information exchanges in other communities. 3) *Ill-defined problems and information need.* The need and motivation for accessing knowledge from unfamiliar communities occurs in practice when people face ill-structured problems that do not fit their familiar contexts. But if the information acquisition process is difficult and the need for information is ambiguous, it will inhibit the cross-community exchange as well. These findings remind the researcher that, when designing cross-community activities, it is important to be aware that the knowledge might be used in various ways because socialization requires large amount of interactions and information communication. Thus, it is important to create opportunities for the community to maximize the socialization and create a knowledge structure representation which enables the growth of continuous of shared domains and participants’ motivation to exchange information with other communities. Lastly, it is vital to have a certain purpose in mind before they explore the boundary area in order to gain more valid information that can best fit participants needs.

Besides the hindering elements illustrated above, similar concerns are expressed by other scholars who consider that the boundary encounter can be hazardous due to open-ended discussions having “the potential to be inconclusive while a lack of openness to the concern of those involved may be alienating” (Kubiak, 2014, P.91). Thus, conveners need to entice people by designing boundary activities that stretch their understanding while also addressing key current concerns from their existing contexts. A careful design of a boundary encounter is also an integral part of reconfiguring partnerships in the landscape of the community. From the studies, Wenger-Trayner & Wenger-Trayner assert that the most successful learning activities tend to “engage people in doing something concretely relevant to stakeholders’ practice and calling for collective engagement in negotiating significant issues” (2014. p. 109). Thus, a successful
boundary encounter experience requires a mutual understanding to facilitate the knowledge
transition and the completion of the common goals. What’s more, by effective design and use,
the boundary object becomes critical to solving existing conflicts and facilitating interactions and
knowledge transitions among different practices of communities. Thus, representations and
boundary artifacts become crucial in facilitating boundary crossing since the potential of their
functions rely upon how they are used. In order to overcome the difficulties of boundary
crossing, it is important to understand the nature of boundary objects and investigate how
boundary objects facilitate the transformation of information and maximize the learning
potential.

**Boundary Brokers**

When boundary crossers cross the boundary, a certain format of consistency is required
for the requirement of mutual understanding and to gain significant cognitive restructuring. This
is because when facing boundary crossing, one common issue is that the broker always needs to
deal with two or more complex landscapes of communities of practices that already have
established histories, domains and regimes of competence (Wenger-Trayner & Wenger-Trayner,
2014). Individuals from one community always focus on their own practice and have their own
competency inside one community; however, brokers active in the boundaries are “trying to
draw attention to matters elsewhere may be seen as [having a] lack of legitimacy” (Kubiak, et al,
2014, p.82). Thus, one needs to identify to different extents with each regime of competence. As
Burt (2005) and Wenger (1998) both explain, brokers work at the boundaries of the landscape
building connections between various practices, introducing practices from elsewhere, and
facilitating cross-boundary experiences. To do so, brokers need to have *knowledgeability*
(Kubiak,2014). *Knowledgeability* is a complex achievement. From one aspect, *knowledgeability*
refers to the individual's competence within a single community. With the expectancy of “identification”, one has strong competence to be accountable (Wenger-Trayner & Wenger-Trayner, 2014, p.24) and the tendency of becoming an “expert” (Giyo Hatano and Kayoko Inagaki, 1984) in the community. Giyo Hatano and Kayoko Inagaki described two types of expertise: routine expertise and adaptive expertise. They found that routine expertise involves mastering procedures in a highly efficient and accurate way, whereas adaptive expertise development requires one to develop conceptual understanding to invent new solutions to problems. They are able to apply knowledge effectively to new problems in a domain, being able to draw their own knowledge to create a new procedure for unique problem solving. In order to innovate and gain cognitive development, individuals must enjoy the environment of “randomness” and a certain degree of freedom to be innovative and exploratory with learning objects.

When brokers face multiple boundaries, it also requires brokers to acquire the second aspect of knowledgeability, which refers to a person’s connection with a “multiplicity of practices across the landscape” (Kubiak, et al, 2014, p.81). The development of one’s knowledgeability involves facilitating cross-boundary learning interactions. These brokering activities conversely increase brokers’ expertise in polycontextuality (Engestrom, 1995) which refers to the expert at the level of activity systems that are engaged not only in multiple simultaneous tasks, but also participate in task-specific frameworks within one and the same activity. However, there is still a research gap in further understanding how boundary brokers manage the coexistence of heterogeneity and collaboration during the boundary crossing process in the Knowledge Building environment, and what the brokers consider the nature and characteristics of boundary objects in Knowledge Building.
Boundary Objects

In real-life scientific practice, most scientific work is completed by tremendously varied groups from different fields, for instance, space aeronautics, computer intelligence, medicine, etc. Scientific work requires heterogeneity as well as cooperation to generate common understandings and valid information to keep a certain level of integrity across time, space and location (Star and Griesemer, 1989). In order to understand how divergent viewpoints and the need for generalizable findings work together, Star and Griesemer (1989) studied the reporting process from two groups of Berkeley’s Museum of Vertebrate Zoology. They found that it is critical to create a framework to enable cooperation among heterogeneous groups of participants. When the frameworks are ill-structured in common use, they become strongly structured in individual site usage which is “adaptable to different viewpoints and robust enough to maintain identify across them” (Star and Griesemer, 1989, p. 387). In order to let the information transfer through different sites, the authors assert that there are two major ways to incorporate findings and make different meaning coherent radically: standardization of methods and the development of boundary objects. Boundary objects are first identified as objects that are “both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identify across sites” (Star and Griesemer, 1989, p.393). Further, the researchers explain four different types of boundary objects in details: repertories, ideal types, coincident boundaries and standardized forms. Thus people from different sites complete the goals where the value of their goals overlap with the process of conducting collective work through boundary objects. To make the process meaningful, it should let individuals “from different social worlds frequently have the experience of addressing an object that has a different meaning for each of them” (Star and Griesemer,1989. p. 412). This also provides a solution to
potential conflicts of communication across communities such as multiple viewpoints, translations and incomplete battles from different worlds. This is because when boundary objects enable collaborative working and sharing of practice across landscapes, they often facilitate communication and coordination by providing a common structure to align activity which is meaningful to all members involved. For instance, a blueprint can help all members to know what their goals are and contribute to collaborative effort. However, the key for boundary objects is they are flexible enough to be interpreted into particular needs. Thus, although the blueprint is an overarching plan, it will not be used in the same way for the same purpose to all involved (Oborn & Dawson, 2010).

This view of point is further strengthened and analyzed by Oswich & Robertson (2009), when they reanalyze the concept of boundary objects based upon their formation as texts by using discursive approaches. They examined two major aspects including: 1) ‘intertextual analysis’ (Allen, 2000); 2) ‘recontextualization’ (Bernstein, 2000) is used to reconsider Sapsed and Salter’s (2004) work on project management tools. The authors investigate how the context shifts from academic field to industry, and vice versa. The author found that “the process of recontextualization involves a sophisticated discursive shift in which the same discourse comes to mean different things in different contexts (p. 183). On the other hand, recontextualization is concerned with the analysis of discourse across different contexts; it has “resonances with the study of boundaries and the process of exchange between different “communities of practice” (p. 183). When boundary objects are treated as textual representations that enable objects or knowledge to be used by various groups, they are acting as “common information spaces that enable the interaction and coordination consensus or shared goals (Bartel and Garud, 2003, p. 333).
However, there are some challenges encountered by boundary objects during the cross-site process. Oswich & Robertson assert that under some circumstances when boundary objects are considered with authorship, readership and plurivocality, they may be seen as barricades and mazes that reinforce existing power structures and occupational hierarchies, and create barriers to change (2009). Star (2010) also mentions another challenge during communications, such as communicative mishaps, as Bateson’s work on schizophrenics called the “trends-contextual syndrome”, which means that the messages that were coming at one level from the systems developers were not being heard on that level by the users, and vice versa. It remains obvious to one but presents as a mystery to another.

The concept of the boundary object has been used in various areas, but what is a boundary object after all? More than two decades after this concept emerged, Star wrote an article about what is not a boundary object from the opposite perspective to further understand this concept. Star (2010) reasserts boundary objects have been used in many forms -- textbooks, performances, computer operating systems, etc., reiterating that “boundary objects are a sort of arrangement that allow different groups to work together without consensus”. What is important for boundary objects is how practices are structured and language emerges for doing things together (Becker Cited by Star 2010). The author first frames the concept to analyze the nature of cooperative work in the absence of consensus, and figured out that consensus was rarely reached, and fragile when it was, but cooperation continued, often unproblematically (Star 2010, p. 604). This point of view also aligns with Engstrom's (1995) results mentioned earlier. The author stresses that the boundary object resides between social worlds where it is ill structured. When necessary, the object is worked on by local groups which maintain its vague identify as a common object, while making it more specific, more tailored to local use within a social world,
and therefore useful for work that is not interdisciplinary. The value of boundary objects is that they exist in each field but enable different sites to gain what they want from the same thing. To explain this concept, Star (2010) used a metaphor of the use of maps -- when a monkey and a human being are looking at the same map, the map reflected in a monkey’s brain does not equal the one reflected in the human brain. Star explained that this is so because the map did not need to serve the same function. For some people, it is just for sharing data, while for other experts, more accurate information is needed. Thus, different sites purposefully identify what they need from the boundary objects.

Boundary objects have been considered from the larger perspective of scale and scope. First, Star (2010) considers the concept of boundary objects most useful at the organizational level in terms of its scale, since it carries interpretive flexibility for a listener or audience. It also relates to social structures which can be explained by Sawyer’s (2005) social emergence theory: when conceptualizing the interactions between processes at different levels, once a frame emerges, it constrains the possibilities for action at first. For instance, the use of interactional resources is an ephemeral-emergent existence which arises from subtle complexities of language usage and small-group interaction. Through repetition within a group discussion, a term or the use of an object might take on a settled significance within the group’s current work until it results in a sediment resource into a longer-term “stable-emergent” form, which retains its meaning across multiple group interactions (Stahl, 2013). Thus, when a resource serves as an institutionalized resource within a structured network, it can serve as a “boundary object” (Star 1989). In terms of scope, under certain circumstances boundary objects are subject to interpretive flexibility. But, the author thinks that the most useful level of scope for the concept is more specific, that is, instead of simply making different interpretations of one thing, it will be more
interesting to study how people make distributing, work arrangements and heterogeneity of a boundary object specifically (Star, 2010). This also involves how different boundary brokers of the community act differently when they use boundary objects during boundary crossing. It remains to be understood how participants in one community use boundary objects in Knowledge Building. Studies are needed to research the nature of boundary objects that facilitate Knowledge Building over time beyond boundaries. There is an urgent need to further understand how students use boundary objects in KB learning environments.

Conceptual Framework: Multi-Level Emergence Design of KB Interactions Across Classrooms

This research tests a multi-level emergence approach to Knowledge Building interactions across social levels, which involve individuals, opportunistic groups, and communities (Csikszentmihalyi, 1999, Sawyer, 2005; Stahl, 2013, Scardamalia & Bereiter 2006).

The Multi-level Emergence Design enables individuals to continue their inquiry-based learning in Knowledge Building environment, and students form opportunistic groups based on their inquiry topics. As the learning progresses, students sharing their learning with their focal class and advance their home community’s knowledge forward. At the same time, students’ can also share their learning with other community members through boundary objects, the boundary object has the same format which increases its readability across communities and enables the information transfer among various communities asynchronously. Another cross-community interaction design element is the public space where allows all participants are working together synchronously to solve challenging problems together. Members from multiple collaborate in the same area to contribute their ideas to solve the more significant challenge. The members who engage in the cross-classroom activities through boundary objects or cross-classroom interaction
also act as the boundary broker and transmit the information from focal space to larger cross-community area, and vice-versa. A multi-layer approach in the emergence of the inquiry progress is reflected the following aspects:

**The generation of boundary objects in the form of the Journey of Thinking**

From the beginning of the Knowledge Building learning activities, individuals involved in the KB inquiry explore knowledge related to their focal interests; they develop their cognitive processes and understanding, and the learning and activities are spontaneous. Students interested in the same questions naturally gather together, conducting initial research to address their burning questions collaboratively; thus the initial group emerges based on students’ mutual interests. Students involved in groups conduct Knowledge Building discourse to interact together. As the learning progress continues, students generate common understandings and common knowledge background. The discourse conducted in each area is increasingly complex and deep. Based on “pre-knowledge”, students continue to generate new research questions, explore new wondering areas, and create synthetic boundary objects. In this study, the synthetic boundary object takes the form of Journey of Thinking (Figure 1). As a reflection of their learning, students create Journey of Thinking with four scaffolds: *Our research question*, *We used to think*, *Now we understand*, *We need to further understand*. Members from each group start to share what they have learned within groups; students reach out to the other groups in the community to make possible connections, share new insights, build-on other ideas, and co-expand the state of the community knowledge through Journey of Thinking.
Cross-community interactions using boundary objects

After the Journey of Thinking has been generated, it is further shared and reviewed with other communities in a common online space. This synthetic boundary object, the Journey of Thinking, enables individuals to understand the discussion and extend the progress of inquiry in other communities. With careful sharing, reading and building-on, these Knowledge Building behaviors further sustain the cross-community interactions. The newcomers can access existing knowledge with a clear purpose facilitated by Journey of Thinking which enables information transmission across communities. As members access diverse ideas and in-depth thinking beyond their current community, extended connections and insights from the broader scale expand the inquiry process and enrich the research contexts. Students then conduct deeper research according to the emergence of the new challenges or new research inquiries along with Journey of Thinking readings and writings.

The downward impact of cross-community dynamics on within-community inquiry and discourse.
**Downward causal effect** refers to the impact of the emergent macro level interactions on micro level KB activities. It is reflected in two aspects, as elaborated below. On the one hand, students co-generate the interactional frame of Knowledge Building norms, metacognitive meetings rules, and distribute workloads and collaborative responsibilities in each group, and co-generate the online discussion norms. These emergent collective actions then regulate and promote their collective actions. These two processes are inseparable and happen simultaneously, which means that the emergence of students’ KB discourse, behavior patterns, and KB norms contributes to the continuing process of collaborative inquiry, but at the same time it regulates and accelerate students’ behaviors in shared KB environment culture by the mutually agreed norms that are created at that moment. The stable material content structures and discursive patterns guide, direct and constrain individuals. However, this guidance and constraint often contains a contingency that is never fully constrained, as the emergence frame is continually evolving.

On the other hand, the collective knowledge of the four classrooms has to tap into the knowledge accumulated at the individual class level because the individual class is the basis of organizational knowledge creation. “Super Talk” is the collaborative online space where students from the four classes work together to address the same challenging problem. The learning results also impact and transform the learning dynamic back to each class and individual student. The accumulation of knowledge created in the online space will leverage each classroom’s understanding when an individual student acts as a boundary broker, bringing these new insights back to their home classes. It leverages the understanding of the home class and also creates new opportunities to reorganize the current classroom’s accumulation of knowledge. The collaborative space and boundary objects not only provide students with an infrastructure which
enables knowledge creation across communities, but also, the knowledge infrastructure provides inquiry and learning with a trustworthy, vetted background database created by students. The visualization of the conceptual framework is shown in Figure 2.

![Conceptual Framework](image)

**Figure 2:** The visualization of the multi-level emergence design of KB Interactions across classrooms conceptual framework

**Research Goals**

The above literature review highlights the need for further understanding the nature of boundary objects and boundary crossing in Knowledge Building communities. Existing research on Knowledge Building has focused on students’ inquiry and discourse within a single community. New advances are needed to support emergent interactions at the higher social levels to enable cross-community interaction for sustained Knowledge Building (Stahl, 2013). Difficulties are revealed for students to understand and build on other communities’ extended discourse without a clear sense of what is going on in specific classroom contexts. In setting up design-based research to explore the dynamics of cross-classroom interactions through Journey
of Thinking as a boundary object, it is valuable to collect both group and individual students’
data in different layers of analysis. Under such dynamic social interaction settings, it is also
crucial to know which individual brings what knowledge to the interactional setting, how it
leverages the community’s knowledge, and how individuals take away knowledge to extend the
learning from such collaborative settings. Keeping the previous research needs and interests in
mind, the focus of this study explores a new possible way to serve these driving needs, which
attempts to bridge different Knowledge Building communities through boundary objects. The
research goals that this research intends to illuminate are:

(a) What characterizes the quality and nature of the “boundary object” generated by the
students?

(b) What kind of cross-community interaction occurs mediated by the synthetic boundary
objects and how do students perceive the boundary-crossing learning process?

(c) How does cross-community collaboration affect the inquiry work in each classroom
community?

(d) What role do the teachers play in facilitating cross-community interaction?
CHAPTER 3 METHODOLOGY AND OVERVIEW

This study adopts a design-based research (Barab, 2010) method. As one of the important research methods, design-based research (DBR) enables the researcher to use a systematic but “flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories” (Wang & Hannafin, 2005, p. 6). It is used to study “learning in environments which are designed and systematically changed by the researcher” (Barab, 2010, p.153). The goal of DBR is usually continued through multiple iterations in naturalistic contexts. It usually involves progressive refinement across iterations to develop new theories, artifacts or practices that need to be generalized to broader scales. The adoption of DBR in this study allows the researcher to go beyond simply understanding of the learning environment as it is, but also involves efforts to change the design in useful ways to influence learning and practices (Barab & Squire, 2004). The focal design to be tested and improved in this research is the concept of multi-level emergent interaction: as the learning interaction goes on within students’ home focal research areas, a higher social level of interaction is supported through a) boundary objects which take the form of the Journey of Thinking synthesizes asynchronically (study 1 & study 2); b) the cross-community collaboration, which takes the form of Super Talk synchronically (study 2 only).

Research Overview

This design-based research includes three components: Pilot study, study 1, and study 2. These built on one another successively to test and refine the focal design approach. The pilot study first focused on testing the generation process and the use of boundary objects. Based on the research analyses and results, study 1 revised and focused on the use of boundary objects on
a broader scale in a different school setting. Then based on research results from study 1, study 2
further revised the boundary object generation process and added a higher level of social
interaction that enables students to collaborate synchronically. The progressive improvements
were all supported by multiple practical data sources and careful data analyses. Details will be
explained in the following sections.
CHAPTER 4 PILOT STUDY

Classroom Context and Design

The pilot study used secondary data which was conducted in one cooperating elementary school in Canada in 2016. There were two grade 5/6 classrooms that studied human body systems for over ten weeks. The classes were taught by two teachers, Mr. B and Mr. M respectively. The cooperating school has been using Knowledge Building Pedagogy in guiding its teaching and learning for several years. Both teachers were very experienced in KB learning environments at the time when the data was collected. In total, there were 47 students (24 students in Mr. M’s classroom and 23 students in Mr. B’s classroom respectively).

During the ten weeks, all students were using Knowledge Forum. As students were focused on their focal inquiries in their community, they shared their ideas in both face to face “metacognitive meetings” and home Knowledge Forum online views. The cross-classroom interaction was facilitated in an online space called “Super View” where students from two classrooms can post notes together and read each other’s’ notes. In this common space, they wrote their Journey of Thinking reflections, which were called “Journey of Thinking” to show the syntheses characteristic of the writing process. It has a common structure and scaffolds of “we used to think…”, “now we understand”, “we need to further understand” to guide students’ writing.

Research Questions

In the pilot study, based on the exploratory nature of the study, the researcher used qualitative methods to provide a rich description of the cross-classroom interactions. The research questions asked:
a) How did the students generate synthetic boundary objects based on their community’s Knowledge Building discourse and inquiry work?

b) How did the students interact with the synthetic boundary objects from other communities for Knowledge Building, with what support from the teacher?

**Data Sources and Analysis**

To provide a rich description of the cross-classroom interactions, the researcher analyzed the data sources involving classroom video recordings, metacognitive meeting videos and transcriptions, and students and teacher interviews. The metacognitive meeting videos were selected when they were discussions of the Journey of Thinking reflections and cross-classroom sharing. Two teachers’ and 13 students’ interviews were used to investigate deeper insight into user's experiences and insights.

Guided by the first research question, the researcher conducted content analysis (Chi, 1997) to understand how the students’ discourses in sharing views relate to their own regular Knowledge Forum views. Two coders independently coded 81 notes (22% of the total notes) resulting in an inter-rater agreement of 98%. To understand the second research question, the author used grounded theory analysis (Strauss & Corbin, 1998); the two researchers read and re-read the transcriptions of the classroom discussions and interviews, created open codes, which were then clustered into primary themes to capture prominent patterns relating to the two research questions. The authors then co-revised the initial codes and themes and discussed any disagreements. The themes were further validated through checking data against the themes, relating and comparing the themes identified from student and teacher data, and triangulating the identified themes across the data sources.

**Results**
a) How did the students generate synthetic boundary objects?

By tracing student KF online discourse in their home views and their Journey of Thinking topics in the common views, as well as qualitative analysis of the video-recorded classroom interactions and student reflections captured in the interviews. The results showed that Mr. B’s students generated 10 research topics, while Mr. M’s class created six topics in their home views. Although the topic of the Journey of Thinking did not cover all of their regular research topics, Journey of Thinking addressed shared and unique topics of inquiry. Both classrooms mentioned topics like the immune system, heart and eyes and the limbic systems, and other unit topics like Puberty and DNA were identified as interesting and helpful for other students in the other classrooms’ metacognitive meeting discussions (Figure 3).

In the process of creating their own as well reading others’ Journey of Thinking, the pilot results show that students engaged in deeper reflection from the cross-classroom sharing. The qualitative analysis of videos and students’ interviews showed the boundary syntheses involved in high-level reflection on progress and gaps, rising above distributed ideas and information sources for coherent understandings. Students reviewed diverse ideas and information based on relevance to their research topics, depth, and importance of the topic. The analysis of the classroom discussions and student interviews suggest that the students engaged in active and substantial interactions with the Journey of Thinking from other classrooms.
b) How did the students interact with synthetic boundary objects?

On average, each of the Journey of Thinking from archived idea threads of prior classrooms was read by 19.83 students. Students read their peer classroom’s Journey of Thinking more actively (34.6 users per note) than those from the prior classrooms. Beyond individual reading, each classroom had a whole class discussion about the information from the Journey of Thinking, followed by further small group discussions. Through qualitative analysis of the video records of the whole classroom discussions and student interviews about how they approached the Journey of Thinking, the following themes show students’ interaction patterns with Synthetic Boundary Objects:

(a) Identifying knowledge from other classrooms for possible connection. In whole classroom discussions, students first identified Journey of Thinking from other classrooms that were relevant and interesting and contained new information, such as by saying “I am interested in K’s note about allergy.” They related the Journey of Thinking to their own understanding in order to comprehend the topics and enrich their learning.
(b) Comparing knowledge work between communities triggering student reflection.

Students discussed how new and unique ideas from the Journey of Thinking helped them to go beyond the limitation of their own knowledge. The teachers facilitated the discussion by raising deeper questions for reflection. For example, Mr. B asked: “What was the idea that came from the Journey of Thinking that you hadn’t thought before and that pushed your thinking further?” A student responded: “Well I never really thought about what side of the brain controls what side of the body, while I already know, but it turns out that, your left side of the brain controls the right side of your body”. Similarly, Mr. M asked his students: “What topic either strikes you as new information or something that you’d like to pick up as a thread and go deeper into?” Two students responded that they learned from the Journey of Thinking about allergies, a topic investigated by Mr. B’s students but not covered by the students of Mr. M. Another student pointed out a deep concept learned from a Journey of Thinking of Mr. B’s class related to their own work: “Me and J are doing immune system,... and we saw these notes about white blood cells, and that was really cool ‘cause white blood cells were part of your immune system. We don’t really know about them individually...Yeah, it was really helpful for us...”

In addition to reflecting on new knowledge and information gained from the other communities, students further adopted the epistemic form of reflective thinking: “we use to think…now we understand…” and talked about their journey of inquiry accordingly. In Mr. B’s class, student EL reflected: “I used to think, there was a person and then they had a brain, and then the brain told the body what to do and that was the end of it, and now I understand that like each part of the body has its own little system.” Student L responded: “Everything is...part of like a system, like everything is like I can say work together.”
(c) Integrating knowledge across communities to develop complementary perspectives and deep understanding.

The Journey of Thinking from each classroom were written by students specialized in the related inquiry topics to selectively synthesize key problems and ideas using simple language. When reading the deep questions and ideas from their partner classroom’s Journey of Thinking, the students needed to unpack the information to understand the journey of inquiry presented, detect gaps of understanding, and bring together the knowledge from their own and from the other community to address the gaps and problems. With their teacher’s facilitation, students engaged in extended discourse to collaboratively solve problems and develop explanations. For example, students in Mr. B’s room discussed the Journey of Thinking about heart holes written by Mr. M’s students (see the following excerpt), which highlighted why heart holes can be dangerous. The students in Mr. B’s room indicated interests in this topic and discussed the specific reasons and mechanisms:

Teacher K: like the heart hole, I heard of them, but I didn’t know how that really works.
Student S: if you can have a hole in your heart, without it, like, immediately, you exploded.
Teacher K: Well, but what was the problem if you have a hole in your heart?
Student D: It’s like really dangerous if the blood mixes.
Teacher K: Right, the blood mixes, but why is it bad if the blood mixes?
Student B: Because if they mix together, if they mix, they will be as bad as like breathing carbon dioxide.
Teacher K: A, do you want to build on?
Student A: Because the blue side like that has no oxygen.
Teacher K: This side, no oxygen (writes “no oxygen” on the blue part of the on the Smart Board).
Student A: And other part has oxygen.
Teacher K: This does have oxygen. So if they mix, it’s like you are breathing air with no oxygen in it, it will be like suffocating.
Student S: (reads the Journey of Thinking) It says the hole is on the septum, which is between the two chambers of the heart. One chamber sends lots of oxygen rich blood to the body and the other chamber sends not oxygen rich blood to the lungs...
Teacher K: I think a lot of people might have thought the heart pumps blood to the body, but it’s more complicated than that. What does it actually do?
Student S: I am pretty sure that the blood comes through without oxygen can go around the body, and then it goes through and then it collects oxygen, gives it to the body, it comes out the other way, it keeps going around in the cycle.
Teacher K: Do you want to build on that, M?
Student M: Well, it goes through all four chambers, well in the right chambers, its deoxygenated the blood in there, and its goes through of the heart, which pumps oxygen inside the blood and then it gets sent out through the body.
Teacher K: So it’s working with oxygenated blood, and blood with no oxygen. C?
Student C: While, pretty much blood with no oxygen goes to the lungs, and the lungs give it oxygen, and then it circles back to the heart, and the heart pumps out.

In line 18 in the above excerpt, the teacher rephrased student K’s question of “how that really works” as “what was the problem if you have a hole in your heart?” He invited and facilitated interactive input from his students, who brought knowledge about the respiratory system and circulatory system to analyzing the impact of heart holes. Building on student input, in line 28, the teacher highlighted that the function of the heart is more than pumping blood to the body and invited students for full explanations. In lines 29-33, students S, M, and C built on to one another to elaborate the explanations. Following the above discussion, the teacher and his students improvised a participatory simulation to demonstrate how the blood travels to collect and transmit oxygen. The teacher played the heart, and three students played the blood cell, lungs, and the rest of the body, respectively, with the whole class involved in discussing where the blood cell should go, and with what changes in the process of traveling.

Discussion

The pilot study analyzed how the synthetic boundary objects support the cross-classroom interactions. The findings showed positive attitudes towards to the Journey of Thinking writing process where students identified it was not a simple summarization, but a change to reorganize their learning progress with a higher-level reflection and identify their knowledge gaps. The interaction patterns between two communities using the boundary synthesis showed a great potential of the archived notes as learning sources to provide diverse ideas that triggered
students’ interests in relating to their interests’ areas. The common structure makes it more readable and interpretable in the cross-classroom interaction.
CHAPTER 5 STUDY 1

Classroom Context and Design

This design-based study tested cross-community interaction among four grade 5 classrooms from one elementary school located in the Northeast U.S. in two consecutive years. Students studied human body systems in science using Knowledge Forum software and Idea Thread mapper software under the guidance of the Knowledge Building pedagogy (Scardamalia & Bereiter, 2006). As the STEM curriculum transitioning into the new Next Generation Science Standard (NGSS), the school district curriculum requirements changed every year align with the new NGSS requirements, which to the change of the length of the human body section each year. In study 1, The learning unit was started from 2016 September to 2017 June, where the science curriculum the human body section lasted for 8 months (Sep 2016-April, 2017) and added one 1-month ecology unit in the end of the school year.

Classroom Settings

All classrooms had high speed WiFi coverage. Each student has one laptop to use during the science class. Various human body models were provided in the classroom. Books of each human body system were displayed on the classroom shelf for students to readily access. Each classroom has half of the area for students to sit on their desk, and a big rug which allows students to gather together to have their metacognitive meetings (Figure 4).
Figure 4. During the metacognitive meeting, students sit on the rug and share their learning, build-on each other’s ideas, and advance the community’s knowledge together.

Other supportive graphs for instance, inquiry cycle, concept map, metacognitive roles were also hung on the walls to intensify the classroom KB culture (Figure 5)

Figure 5. The Inquiry cycles and Knowledge Building roles posters that hang on the classroom wall
**Teacher Participants**

Two teachers, Mrs. G and Mrs. K, each teach science in two classrooms. Both teachers participated in this dissertation research for two years. Mrs. G has more than 30 years of teaching experience, and more than 3 years of Knowledge Building pedagogy teaching experience. She is very responsible and active in using new technologies in her own class. She always actively follows up students’ latest understanding and pushes students to go forward and step out of their comfort zone. At the same time, she is very good at creating a safe environment which allows students to share their things and ideas, encouraging them to polish their ideas with collaborations. Mrs. G also good at using the analogy and metaphor that children can understand to facilitate students’ learning. Mrs. G is good at keeping track of each students learning progress systematically. Mrs. G taught her own class, as well as Mrs. M’s class.

Another teacher, Mrs. K, has more than 20 years of teaching experience, and has also worked with the researcher closely for more than 3 years using Knowledge Building pedagogy. She is very supportive in Knowledge Building learning. She has a great energy triggering students’ wondering in science and actively asking students questions to let them identify what they want to learn to deepen their understanding. She is very good at arranging the meta-cognitive meeting to encourage students to participate in and actively address the research questions that are “at stake” (Scardamalia & Bereiter, 2003). She often makes experiments which help students’ understanding, and offers a sufficient amount of help according to the level of students’ needs. The teacher also helped students co-monitor and co-generate their wondering areas and learning activities in the Knowledge Building environment.

To help students conduct the study, the researcher and the teacher holds monthly teacher meetings to reflect on students’ Knowledge Building activities, making changes according to the
students’ current understandings, monitoring community progress and making short-term plans to actively extend students’ Knowledge Building activities. The teachers and the researchers also co-design the learning activities according to the emergent learning structure. All of these proceedings were recorded.

**Student Participants**

There were 93 grade 5 students from four classrooms participating in the study. There were 46 boys and 47 girls. Demographically, the 5th grade is more than 90% European-American, and under 10% minority Asian-American and African-American. The majority of students were familiar with computer operations, since they have used the computer since kindergarten. All classroom can access WiFi. Each student has one computer to operate for their research individually. For students who had disability with reading and writing, accommodations were provided for these students including suitable learning methods allowing them to engage to the best of their ability. For instance, students with writing issues used video or audio to record their thinking and post it online, and more easily understandable books were offered to meet their understanding levels, etc. All students were encouraged to take high-level responsibility for generating inquiry questions and developing and refining ideas using various resources.

**Consent Forms**

Before collecting the data, since the grade 5 students belong to vulnerable group, first, students’ parents were informed about the study and asked to complete parents’ consent forms, the researcher sent the forms to parents via letters to home in the beginning of the school year. After around two weeks, the researcher started to receive forms back and collected the consent forms from the parents. The researcher inputted the information on an Excel file to record and track the details. For parents who give the permission to allow their child to participate in the
study, researchers distributed a consent form to their child. However, for those parents who did not give consent for their child to be part of this study, a consent form was not distributed to their child. According to their consent form results, the researcher updated consistently, and brought consent forms to the observation field.

**Research Design: A Multi-Level Interaction in Study 1**

With the positive results from the pilot study, in Study 1, the participants expanded to four grade 5 classrooms. The whole human body inquiry started with a kick off activity with a set of hands-on activities that require students to use their body to achieve various challenging demands, for instance, students were required to cover their eyes and turn for 10 rounds and throw a ball in a designated direction; students wore an oven mitt to move small puzzle pieces from one site to another, etc. Students in each room generated various interests and questions and formulated sharing wondering areas, which directs students’ subsequent inquiry (Figure 6).

*Figure 6. Students created their first wondering areas based on the similarity of their initial research questions.*
As the learning continues, students in each classroom contribute to and build on one another’s ideas by writing notes in their own classroom’s Knowledge Forum online views (workspaces) as students gain their knowledge about their specific areas (Figure 7).

Figure 7. Knowledge Forum local group working Interface

With inquiry progress made in the first eight weeks, students were introduced to the cross-classroom “Super View”. The Super View space includes a section for each of the four classrooms together with a collection of all Journey of Thinking created by previous classrooms that studied the human body (Figure 8).
Figure 8. A set of Journey of Thinking were selected and posted in students “super view” for them to read as supportive reading materials.

A visual was added to the Super View involving four puzzle pieces to connect the four classrooms (Figure 9). The students first selectively read the Journey of Thinking from the previous classrooms. As students in each classroom make progress in understanding various human body systems, they work with their peers to review their journey of thinking and co-author it to synthesize their inquiry for cross-classroom sharing.

To support students’ reflective review and structuring of distributed online discourse, this study used the aforementioned new technology tool Idea Thread Mapper (ITM) to sort out the valuable notes (Zhang et al., 2015). Each post is organized using four Journey of Thinking scaffolds including: Our research topic and problems, We used to think..., Now we understand..., We need deeper research. Extending the online sharing and interaction, students had conversations to discuss what they learned from the other classrooms, identify connections, and build on the information gained for deeper research.
Figure 9. The “Super View” with both previous year’s notes and current year’s Journey of Thinking

Research Questions

The research questions in this study are:

(a) What characterizes the quality and nature of the “boundary object” generated by the students?

(b) What kind of cross-community interaction occurs mediated by the synthetic boundary objects and how do students perceive the “boundary object” learning process?

(c) How does the cross-community collaboration affect the inquiry work in each home classroom?

(d) What role do the teachers play in facilitating cross-community interaction?

Data Sources

There are seven primary data sources for this study: a) students’ Journey of Thinking; b) students’ regular notes on Knowledge Forum/ITM; c) class observation videos; d) Journey of
Thinking reflection forms; e) interview transcriptions of students and teachers, f) social network data of Knowledge Forum/Idea thread Mapper entries and reading histories, g) the authors’ field notes during classroom observations.

Most of the research questions were investigated based on notes that students posted in KF/ITM; other interviews and reflection forms were used as supporting data sources. Multiple data sources were used to gain better understanding of the phenomenon under investigation, and support triangulation of the data for the purpose of improving the validity of research findings when the same themes emerge in different sources (Patton, 2002).

a) Journey of Thinking: Journey of Thinking is students’ reflection of their best knowledge, it is supported with four scaffolds: “Our research question”, “We used to think”, “Now we understand”, “We further need to know”. In these two years, the writing process of Journey of Thinking updated.

In study 1: Students in each group first gathered together based on their research topics, and discussed the content of their Journey of Thinking. Students self-selected a student to write their summary in the computer, all the group members names were showed up an co-authors. The final Journey of Thinking was posted in an open online space (Super view) which is accessible by everyone (Figure 9).

The Journey of Thinking as a boundary object in this study was examined carefully from the generation process, students’ perceptions, usage in cross-classroom interaction and teacher’s support during these processes. Their online posts information includes their regular notes contexts, and their Journey of Thinking entries which were collected for further analysis. Students self-identify the when to write a Journey of Thinking. After sharing the Journey of
Thinking, students read, and discuss others’ Journey of Thinking reflections. Various means of the use of Journey of Thinking has been revealed in the research as shown in the results.

b) Students’ online notes on KF and ITM. Start from the beginning of the school year, students were introduced to share their knowledge on KF/ITM, in the first month, students first introduced how to write a regular note on KF/ITM, and get familiar with the interfaces. A regular note allows students to record their new learnings, to share resources like pictures, videos, gifs and to organize their ideas by using scaffolds that has been tested in the pilot study, like “New information that I learned”, “I need to know more about” (Figure 1). More importantly, regular KF notes enable the continuation of students’ online conversation and learning, students can login KF/ITM outside of the science class anytime and anywhere. For instance, and they can use their free learning time during the day to browse peers notes, they can also access to the KF/ITM at home to post ITM notes as homework. More importantly, by using the function of “Build-on”, students are able to connect one’s idea to the others’, and add new insights, critique, ask questions. Through these online learning activities inside/outside of the science classes, students created a learning network and learning momentum through these social interactions.

c) Class videos: In order to capture how students and teachers interact with Journey of Thinking at school, the researcher set up a camera in the back of the class to record the class procedures. For students who do not have their parents’ consent to be videotaped or who do not want to be videotaped, their seats were arranged out of the camera’s view to avoid their images being captured. For small group activities, the researcher added more cameras to capture each group’s discussion in detail. In study 1, the researcher recorded (116) of videos, each last around 30-60 minutes These videos were further divided and selected guided by the research questions. All the videos have been saved in a safe place with lock and passwords. When the situation is
needed, for instance multi-group discussion, cross-classroom interaction, the author also extra
audio-recorders to make sure capture the classroom activity at maximum.

d) Field notes: In order to capture the detailed interaction of how students create and
interact with the Journey of Thinking during the class period. The researcher made a special field
note which has all students’ names on it, and wrote down the process/behaviors that students do
during the class period, to record important moments and provide rich data for later use. The
researchers organized the field notes after the observation. Researchers tried to capture the
highlights of the classroom activities. Also these field notes notes helped the researcher to better
track of each students’ progresses and learning activities.

e) Journey of Thinking reflection form: After students finish the cross-classroom
interactions, and Journey of Thinking writing and reading activities, students from Mrs. K/Mrs.
M’s two classes filled out an individual reflection form that asks students’ reflections about the
use of Journey of Thinking, including: What is a Journey of Thinking? How are Journey of
Thinking helpful to you? When you read the Journey of Thinking, Did it make you have any new
wonderings? How will you use Journey of Thinking in the future? Later the researcher did a
content analysis based on their answers.

f) Interviews: 1) Students Interviews: In order to deeply understand students’
perceptions of cross-classroom interactions, a semi-constructed interview has been conducted. In
this procedure, only students who consented as participants in an interview selected. The
interview protocols were designed to capture the students’ learning experiences and their
reflections in a deeper level. In study 1, 20 students agreed to be interviewed; in the first year,
the researcher chose 20 students who gave consent forms for this study. Each interview took
around 20-30 minutes. Students were taken to a quiet private classroom, and had their Journey of
Thinking open in a computer, and the whole process was both videotaped and audio taped. After the interview, the researcher transcribed all the video/audio and then put the transcripts into Nvivo12 did a further quantitative analysis. The interview questions were related to inquiry based learning as well as their Journey of Thinking using experiences, for instance, one questions asked “How do you think your own research is connected to the other topics that other classrooms students or prior classroom students have been working on or had been working on?”

2) Teachers’ Interview: At the end of the school year, each teacher has been interviewed around 30-40 minutes individually. In the first year, the interview protocol was initially designed to focus on the teachers’ inquiry process and initial round of cross-classroom interactions. The interview was conducted in their home classroom with a one-on-one face-to-face setting. The interview used both video-recording and audio-recording at the same time. In order to fully engage in the conversation, interview notes were taken to record the highlights of the teacher’s reflections. After the interview, the researchers read and re-read the interview, and carefully transcribed the video files.

All of the posts were saved in the system background server automatically. The researcher retrieved the data from both the Knowledge Building and ITM interface as well as the database. In this study, students posted their notes to an open space on KF Social network data of online entries and reading histories: In order to further understand how students interacted through boundary objects, the background information was collected involving notes creation time, online posts reading histories, building on trajectories to understand students’ interaction patterns.

**Data Analysis**
**Grounded theory**: To understand the first research question regarding what characterizes the boundary objects generated by the students and the second research question of how students perceived the boundary objects, the author used a grounded theory approach (Strauss & Corbin, 1998) for investigating students’ cross-classroom learning process with the facilitation of Journey of Thinking. The author first selected the materials that related to the cross-classroom interactions and online notes and students’ Journey of Thinking reflection forms. The author then transcribed all the students’ and teachers’ interviews and classroom videos that related to cross-classroom interactions. This was done in collaboration with another graduate student who is also familiar with Knowledge Building pedagogy. Both coders went through the Collaborative Institutional Training Initiative (CITI)’s training course about human research subjects, coded the data separately, and generated and compared the initial coding. After discussion and clarification of the meaning of each coding, two researchers revised and set a clearer definition of each code and further revised the coding sets until the coding list captured and reflected all the aspects of from the materials. Because the data size is relatively small, so the second coder reviewed 100% of the data. Two coders coded these notes and transcriptions independently. Then the researchers read and re-read the transcriptions of the classroom discussions and interviews and created open codes which further clustered into primary themes to capture main patterns. After co-reviewing the open codes and initial themes, two researchers solved disagreements through more discussions. The initial themes further validated through checking data against the themes, relating and comparing the themes, and triangulating the identified themes across from students and teachers’ data. The refined coding themes were used to answer the research questions.
**Qualitative analysis:** To better understand the second research question regarding how students perceive the “boundary object” learning process and the fourth research question regarding what role the teachers play in facilitating cross-community interaction, the researcher conducted one-on-one interviews. The semi-structured interviews offered the researcher more opportunities to get details and in-depth insights from the participants about what they experienced and what their perceptions were. The researcher was well-experienced in conducting interviews and asking questions. Two researcher first transcribed the interviews and metacognitive meetings videos, after read and re-reading the transcriptions, two researchers started to code the whole text separately. By searching for the themes with broader patterns, the author generated the initial coding, by reviewing themes, the researcher makes sure the initial codes fit the data. Then, the two researcher redefined and naming themes and further revised the themes together through discussions.

**Content analysis:** To examine the nature and quality of student Journey of Thinking writing, the researcher traced the Journey of Thinking created over time and conduct content analysis (Chi, 1997) to categorize the topics, nature of questions (e.g. general vs. specific, and types of information searched), the scientific levels (from pre-scientific to scientific), and complexity of ideas (from unelaborated facts to elaborated explanations) (Zhang et al., 2007).

**Social network analysis:** To understand how students interacted through the Journey of Thinking, the researcher used the social network analysis software UCINET (Borgatti et al, 2002) to examine who had read whose Journey of Thinking among the four classrooms. Furthermore, the researcher traced the classroom activities and discourse in which students refer to and discuss the Journey of Thinking for idea connection and deeper inquiry.
**Discourse analysis:** Supporting the classroom discourse analysis, the researcher also asked students to individually reflect on their Journey of Thinking learning experience based on four guiding questions: What topic are you currently studying? What were the topics of the Journey of Thinking that you read? What new knowledge did you gain by reading the Journey of Thinking? How are the Journey of Thinking helpful to you as a science learner? To understand how do students work with Journey of Thinking and what are their perspectives of Journey of Thinking writing.

To examine the teachers’ role in facilitating cross-classroom interaction, the researcher interviewed the teachers at the end of the school year focusing on their classroom practices and strategies. The classroom discourse, student reflection, and teacher interviews were analyzed using a grounded theory approach (Strauss & Corbin, 1998).

**Results**

(a) **What characterizes the Journey of Thinking and how did students generate the Journey of Thinking to reflect on inquiry processes for cross-community sharing?**

To provide a whole picture of the Journey of Thinking generation process, the author first traced the temporal process by which the four classrooms generated the “Journey of Thinking.” Figure 4 shows the number of Journey of Thinking (n=56) posted by each classroom in the different months from November to April. As the figure suggests, students’ Journey of Thinking reflection generation pattern has been sporadic (Figure 10).
Figure 10. The number of Journey of Thinking created by classroom K, M, G, and W over time.

The researcher further analyzed the content alignment between students’ Journey of Thinking and their regular online discourse in their local views.

To understand the content topics of students’ Journey of Thinking and the connections with their regular online discourse in their local views, the author conducted content analysis to code the topic of each Journey of Thinking based on the human body systems. The same coding was implemented for the regular notes created by each of the four classrooms. Figure 11 reports the topic distribution of the Journey of Thinking and Figure 12 shows the topic distribution of students’ regular note written in their local online discourse.
As Figure 5 suggests, the Journey of Thinking from the four classrooms documented inquiry progress in shared topical areas as well as areas somehow unique to the different classrooms. As a general pattern, students posted more Journey of Thinking in the areas that had been most intensively discussed in the local discourse space. At the same time, students also posted Journey of Thinking about a few specialized topics that did not have heavy discussions in their classroom. They considered these topics as interesting and potentially helpful for other students.

To gauge the quality of student reflection on their journey of thinking documented in the Journey of Thinking, the author coded students’ ideas summarized in the Journey of Thinking under “We used to think” and “Now we understand” based on two dimensions: scientific sophistication and epistemic complexity (see Zhang 2 et al., 2007). The coding categories and
results are reported in Table 1. In terms of scientific quality, students’ prior ideas identified under “We used to think” are mostly pre-scientific misconceptions (38%) or hybrid ideas mixing scientific information with misconceptions (48%), while their updated ideas summarized under “Now we understand” are scientific or basically scientific. Compared to their prior ideas, the updated ideas also show higher levels of complexity, mostly presenting elaborated explanations or elaborated facts. These results show that the students were able to reflect on substantive inquiry progress and synthesize complex scientific ideas for cross-classroom sharing.

Table 1

Coding of Ideas in the Journey of Thinking Summarized under “We Used to Think” and “Now We Understand.”

<table>
<thead>
<tr>
<th>Coding dimension and category</th>
<th>We used to think</th>
<th>Now we understand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Sophistication</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Pre-scientific</td>
<td>38%</td>
<td>0%</td>
</tr>
<tr>
<td>2-Hybrid</td>
<td>48%</td>
<td>0%</td>
</tr>
<tr>
<td>3-Basically scientific</td>
<td>14%</td>
<td>18%</td>
</tr>
<tr>
<td>4-Scientific</td>
<td>0%</td>
<td>82%</td>
</tr>
<tr>
<td><strong>Epistemic Complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Unelaborated Facts</td>
<td>95%</td>
<td>9%</td>
</tr>
<tr>
<td>2-Elaborated Facts</td>
<td>0%</td>
<td>32%</td>
</tr>
<tr>
<td>3-Unelaborated Explanations</td>
<td>5%</td>
<td>9%</td>
</tr>
<tr>
<td>4-Elaborated Explanations</td>
<td>0%</td>
<td>48%</td>
</tr>
</tbody>
</table>

The author further coded students’ reflection on their inquiry questions highlighted in the Journey of Thinking including questions explored so far (“Our research topic and problems”) and deeper questions. The coding categories and results for this analysis are reported in Table 2, showing the wide range of questions asked by students. Students generated more questions after writing Super Notes. They asked more specific questions within their own research areas. Questions identified for deeper research focused on more specific issues seeking elaborations of reasons and mechanisms.
Table 2.
Coding of questions in “Journey of Thinking,” including questions explored and those for further research.

<table>
<thead>
<tr>
<th></th>
<th>Question explored</th>
<th>Question for further research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total questions</td>
<td>72</td>
<td>87</td>
</tr>
<tr>
<td>Broad questions</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Specific questions</td>
<td>52</td>
<td>77</td>
</tr>
<tr>
<td>Substance/Definition</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Characteristics</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Function</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td>Reason/explication</td>
<td>18</td>
<td>32</td>
</tr>
<tr>
<td>Relation Connection</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Conditions and Consequences</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

For example, on November 16, a group of students from classroom K who had conducted deep research about blood and cells were first introduced to the Super View. They first read previous Journey of Thinking related to their topics, such as blood, cells, and DNA. They then had a small group discussion about what they learned from these Journey of Thinking and what they would like to share in their own Journey of Thinking. Later they created their first Journey of Thinking: “Journey of Thinking about blood.” Teacher K introduced the Super View to her whole class on November 30. She showed the previous years’ Journey of Thinking as model for her students, and encouraged them to read topics that interested to students. Students working on productive areas of inquiry were encouraged to write their Journey of Thinking to share their journey and progress of inquiry.

To understand how students approached their Journey of Thinking, the researcher analyzed their perceptions of the nature and purpose of the Journey of Thinking based student interviews. Major themes are summarized in Table 3.
Table 3  
Students’ perspectives of the Journey of Thinking based on interviews

<table>
<thead>
<tr>
<th>Themes</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journey of Thinking as summaries of</td>
<td>I decided to go with the main things that I learned, the things I spend the most time on, like a few weeks, not the things like I found out like in five minutes.</td>
</tr>
<tr>
<td>big ideas</td>
<td></td>
</tr>
<tr>
<td>Journey of Thinking presenting refined</td>
<td>I wanted to take my really good really deep thinking really good information to put into it. so it’s really like the best of the best information that I had.</td>
</tr>
<tr>
<td>ideas</td>
<td></td>
</tr>
<tr>
<td>Journey of Thinking</td>
<td>You join together with your whole group, and put together all of your knowledge and questions, and like deeper research questions in the beginning, into one note, that’s like super huge, and now a lot of key words you have to use to make it.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Journey of Thinking</td>
<td>To show that I studied all of this and now I’m putting all my information together to show other people and to teach other people, these are the big things that I’m learning about. Because not just your class could see it, it’s everybody</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Journey of Thinking</td>
<td>…People gonna become fifth graders when they come, it can help them, they can look at our Journey of Thinking and learn more stuff from me</td>
</tr>
</tbody>
</table>

Qualitative analysis of classroom discussions and student reflections showed student work with the boundary object in cross-classroom interactions. The Journey of Thinking facilitated students’ deepening of their research, seeing relationships between different organs and systems, and generating deeper questions for sustained inquiry.

b). What kind of cross-community interaction occurs mediated by the synthetic boundary objects and how do students perceive the “boundary object” learning process?

Social network analysis was used to examine who had read whose Journey of Thinking among the students from the four classrooms. Figure 13 shows the extensive social connections formed among the students through the mutual reading of “Journey of Thinking,” including
reading the Journey of Thinking created by peers from other classrooms and those from their own classroom. The densities of the reading interaction within each home classroom are slightly higher than those of cross-classroom interaction. But overall, the homophily measure (E-I index = .08, within the maximum range from -1 to 1) shows a balance between within- and cross-classroom interactions.

In the Super View, students also read some of the Journey of Thinking from the previous school year. The author used the principal component network analysis to examine student reading of Journey of Thinking from the same school year vs. from the prior students. As Figure 14 shows, the reading interactions among the current students were much more extensive than reading the Journey of Thinking from the previous year, homophily E-I index = -0.50 (in the range from -1 to 1).

![Figure 13. Social network analysis of who had read whose Journey of Thinking among the students from the four classrooms. Each node denotes a student. A line linking two students shows a social tie created through the read.](image-url)
Researchers conducted semi-structured interviews to investigate how students benefited from the Journey of Thinking generated by peer and previous classrooms. Students reflected that the Journey of Thinking from previous years helped them in their learning because Journey of Thinking offered more information that students did not know. When students clicked the Journey of Thinking from the same wondering area from the previous year’s students, they were easily building connections and inquiry in that same area. Some students also reflected that the previous years’ Journey of Thinking helped them to get started on a new research topic since the existing topics broadened their views. Some other students also picked up the remaining research questions and built off of them. The big chunk of knowledge in the Journey of Thinking which contains students’ best knowledge also saved other students time in looking up related information instead of clicking regular small Knowledge Forum notes one by one (Table 4). Similarly, students conceived Journey of Thinking from peer fifth graders as offering them new information about what they considered important. However, reading current classmates’
Journey of Thinking will help students to navigate and understand their classmates’ progress in their own inquiry area and get a sense of what they will share in the metacognitive meeting. Students also reflected that by looking at the topic areas, Journey of Thinking offered them choices to look at different topics and prepare for their next topic. For students who don’t know how to write a reflection, the Journey of Thinking functioned as models in their writing.

Table 4
How Students work with Other Grade 5 Classrooms’ Journey of Thinking

<table>
<thead>
<tr>
<th>How students worked with the Journey of Thinking</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content:</strong></td>
<td></td>
</tr>
<tr>
<td>Gaining new knowledge</td>
<td>I learned about a lot of new things and there are even some that I have never learned about before.</td>
</tr>
<tr>
<td>Offering deeper knowledge and research about one’s topic</td>
<td>A lot; they give me deeper research about the eyes.</td>
</tr>
<tr>
<td>Answering students’ questions</td>
<td>Very helpful. They answered a lot of my questions!</td>
</tr>
<tr>
<td>Triggering new wonderings</td>
<td>Because they had some information I didn’t know and made me wonder a little bit more about it.</td>
</tr>
<tr>
<td>Facilitating deeper thinking</td>
<td>They taught me a lot new things about blood and the heart. And made my thinking a lot easier.</td>
</tr>
<tr>
<td>Inspiring sustained inquiry in one’s topic</td>
<td>They made me realize I didn’t want to switch to bones because there is still more to learn about cells.</td>
</tr>
<tr>
<td>Seeing and connecting with other people’s thinking</td>
<td>They offer opportunities to see other people's thinking as a science learner.</td>
</tr>
</tbody>
</table>

| Structures and Functions:                       |          |
| The structure is easy to navigate               | They made it clear who was saying what. It was very organized and I learned a lot. |
| Modeling super note writing                     | The “super notes” gave me more information so I could make a “super note” on what I learned. |
| Showcasing knowledge builders                  | The “super notes” were helpful; it makes me a better learner and I feel smart. |
c) How does the cross-community collaboration affect the inquiry work in each home classroom?

While students accessed the Journey of Thinking in the Super View on an ongoing basis, students in each classroom continued to conduct deeper inquiry and participated in metacognitive meetings to discuss their understandings and challenging issues. In several of the classroom meetings, students reflected on their own inquiry in connection with the new insights gained from other classrooms and developed deeper understandings. For instance, Student A1 from classroom T, who was studying the heart and nutrition, read a Journey of Thinking from the previous student cohort class about the digestive system. She made an idea connection to address her research question, and shared her insights at a classroom meeting (See Table 5).

Table 5
Excerpt of one metacognitive meeting about Journey of Thinking in the Super View

<table>
<thead>
<tr>
<th>Transcription</th>
<th>Progress</th>
</tr>
</thead>
</table>
| Teacher G: Is there anyone who branched out beyond muscles and bones brain, heart and lungs. A1(student) where has your research taken you.  
Student A1: Actually G(student) is also doing it with me, first I went to heart, all because of this one episode of one TV show that I watched, it got my attention. Then after that, I kind of got more into potassium, and less about the heart, so now I am not really studying on that branch.  
Teacher G: You got off the heart branch.  
Student A1: I am in digestive system, but I’m kind of in the middle of that, and just know the system, just like potassium.  
Teacher G: So why is it you are hovering between heart and digestion? There is a twig, the potassium?  
Student A1: I guess so, so at first, me and G(student) were wondering what potassium does to the heart, and mainly how it gets there, so then we knew that you eat it in food like citrus fruits, so then we thought how does it gets to the heart, and our big question for a couple weeks was how does it gets into the bloodstream, so we knew that you ate it, and it goes down your esophagus, and then it gets to your stomach, and goes to the digestive system, but what we didn't know from the Journey of Thinking, we read it that we are a little flaps in your intestines, for nutrients to go on the bloodstream, so we found out that’s how I gets Students identify their own research progress and gap Students connect their learning with Other’s Journey of Thinking |
into the bloodstream and the circulation takes it to the heart, and that's how your heart gets potassium.

Teacher G: And knowing just how the heart gets potassium what else can you infer? Does my body only need potassium for my heart?
Student A: No, different chemicals and nutrients that it needs.
Teacher G: Chemicals and nutrients, what do you think A2(student)?
Student A2: I was just thinking cause I know A1(student) actually send me a link, it was about this a guy put a little big potassium and put it into the water and it looks so cool, the potassium is looking like a fireball.
Student A1: It reacts in the water, so I sent it to A2(student), I know you don't study potassium, but G(student) and I were, but you study the heart, and I think this could help you understand how potassium like boost the heart, like how it strong, it has energy in it.
Student L: That kind of helps me because I read something to the digestive system, I was wondering how the blood got nutrients, so I was researching about it, so A1(student) just kind give me like the answer, 'cause the nutrients probably go into from there, so the blood picks it up.
Teacher G: So initially were you studying...
Student L: heart
Teacher G: ...and where did the idea of nutrition jump out at you...
Student L: cause the blood carries nutrients to your body.
Teacher G: So you telling me that it will give oxygen and you were wondering where it coming from and get nutrients. So you're kind of looking at digestion as well.
Student A2: A(student), she is studying the heart and the lungs, um but this is still connected to the heart, just A(student) learning as much for it, but I want to learn more about the blood because I actually got this book where I got this book, I was reading the book about blood.

At this meeting in classroom G, student A first shared her reflection on the inquiry of heart and digestion in collaboration with a peer. Reading a Journey of Thinking from the prior school year about how the small intestine absorbs nutrients, which was written by a student from the prior school year, student A and G gained an important insight in how potassium gets into the heart. Student L further followed up to share a related thought about how nutrients probably go into the bloodstream in general. Building on the information gained, student A and B developed the understanding of how potassium enters the bloodstream and gets to the heart. Student L
further followed up to share a related thought about how nutrients probably go into the bloodstream in general.

The author further analyzed students’ reflection on their experiences with writing and reading Journey of Thinking. Students commented that the Journey of Thinking were helpful in a number of ways. For example, they found that the contents of the Journey of Thinking offered insights directly related to their questions, provided deep knowledge in various areas, which triggered new wonderings and thinking and inspired deeper inquiry among students.

Besides the typical reading activities in Knowledge Forum, Journey of Thinking also provokes students’ inquiry and enables them to pick up the remaining research questions from others. For instance, two students from 5K were studying eyes as their primary focal inquiry. After they read the Journey of Thinking from previous years, they were very interested in one research question from the "We need further research" section from last year's eye group: Why do people have color blindness? Because Student B and Student A already gained basic knowledge about the eyes’ function, this question triggered their research interests of the malfunction of eyes. So they picked up this remaining wondering and conducted further research to find out the answer, and they created another Journey of Thinking based on their new studies. Moreover, a “big question view” was created to fulfill students’ request for deep research question solving across the classrooms.

Students’ cross-classroom collaboration was not limited only to the online environment, they also visited peer classrooms and brought their learning models to share knowledge. For instance, two students who were studying bones in 5 M brought real cow bones and shared their knowledge from their home class. Further, they were invited to 5 K’s class to share their knowledge in 5 K’s bone metacognitive meeting. During the meeting, student J from the bone
group in 5 K had a profound conversation with them, and they generated a new research question, “How did the blood get out from the bone”. As this research question was beyond their understanding, J decided to continue his work in bones and to pursue this problem.

**d) The teachers’ role in facilitating cross-community interaction**

The teachers’ role was investigated through the qualitative analysis of the classroom video records cross-validated by the teacher interviews. To co-design the cross-community interaction, the teachers met with the researchers to review the procedures used in our first iteration (at a different school) and revised the process for their context. As the human body inquiry unfolded, they observed their students’ work in each classroom to monitor student individual progress and emerging shared areas of inquiry. They then introduced the Super View to each of their classrooms and explained the purpose of this view for cross-classroom sharing and collaboration as a broader space connecting the four classrooms. They selected relevant Journey of Thinking synthesis from the previous years’ classes as examples to show what they looked like. Students were encouraged to read the Journey of Thinking from the previous and the current peer classes, and to reflect on their own knowledge and identify the knowledge connection and gaps in the broader picture of human body systems. Both teachers encouraged students to make purposeful and reflective decisions, including selecting the Journey of thinking that they should read as relevant to their needs and interests and deciding when they were ready to write a Journey of thinking based on their progress. Both teachers made efforts to provide the time and space needed for students to pursue a deep inquiry in each classroom while reflecting on their inquiry progress and connections.

What did teachers notice and prepare before the MM about Journey of Thinking?

Through the qualitative analysis of the classroom videos and teacher interviews in the end of the
semester in relation to the video records of metacognitive meetings, the researcher found that as students continue their inquiry and conduct deeper research, teachers will regularly have one on one discussions with students to understand where the class is in the overall flow of the inquiry cycle, to encourage them to explore deeper or other related topics, do more hands-on activities, keep students motivated and engaged by making sure they have a way of sharing the communication in both online or metacognitive meeting, validate what students are working on and provide positive feedback. In doing so, teachers have a more accurate understanding of the advanced idea improvements, and they gain new insights into the class. Then teachers will invite and encourage students to share their cutting-edge information in the metacognitive meetings.

In the interview, both teachers emphasized their role in developing students’ reflective awareness the value of their own deep inquiry in the context of cross-classroom sharing, which gave rise to the excitement to share their knowledge with the other classrooms. Knowing that their Journey of Thinking would be read by the broader audience from the peer classrooms, students felt motivated to conduct deep inquiry and create high-quality knowledge syntheses, and recognized the value of such work that could impact more people and benefit their learning. Reading Journey of Thinking from other classrooms gave students a sense of connection with other learners. It was helpful to clear up some of the students’ misconceptions, and to open their eyes to broader topics and deeper questions, which might be incorporated in their own inquiry and discussion.

The teachers also reflected on some of the challenges. A teacher commented that writing Journey of Thinking required a high-level self-directedness among students so they could engage in meaningful reflection and mutual learning. The teachers suggested that the cross-classroom
sharing should start earlier in the learning process and be scheduled more routinely to leave
enough time for more extensive interactions.

**Discussion**

Study 1 explored new designs of multi-level structure to support interaction across
multiple KB communities at a larger scale. As the local focus research groups generated deeper
understanding, students have accumulated rich information to create the boundary object. The
boundary object takes the form of the Journey of Thinking in this study, enables the information
transfer among the network of communities (Table 3). The multi-level structure allows students’
social interaction in a broader landscape with their peers.

To understand the characteristics of the Journey of Thinking, the first research question
examined students’ generation of Journey of Thinking based on their inquiry progress. The
analysis of the temporal profile and topic distribution (Figure 5) suggests that students created
the Journey of Thinking through a spontaneous, emergent process. The discussion and posts
among the focal groups from each home classroom offers students more information resources
which lead to more Journey of Thinking reflections (Figure 5&6).

The Journey of Thinking reflects students’ high-quality reflections on their learning
processes and shows deep, scientific and complex understandings of each research topic. The
scaffolds also facilitated students to seek more exploratory research topics (Table 3). Reflecting
on the generation of the Journey of Thinking, students identified deepened their research gaps.

To understand the patterns of cross-community interaction and its influence on the
deepening work in the home class, through reading one another’s Journey of Thinking, students
formed extensive connections with peers within the homeclass, as well as other classrooms (see
Figure 7). As part of the cross-community interaction, students also read some of the Journey of
Thinking generated by the previous student cohort according to the needs of their learning and interests of the research topics. There were more active connections built among the students from the current four classrooms than with those of the prior school year (Figure 8), possibly due to social familiarity and proximity.

The analysis of the third research question about the discussion and sharing in the home class metacognitive meeting illustrated how and what students learned from the cross-community interaction, where students identified the knowledge gaps, found the connection with the Journey of Thinking notes, and deepened their understandings of how the human body systems work together. The cycles of information flow suggests how the ideas from cross-community space were further cycled back to each classroom to develop deeper understandings and inspire deeper collaboration and inquiry.

The analysis of the fourth research question elaborated the teachers’ role in facilitating the cross-boundary interactions. As the teacher interviews and classroom videos revealed, the teachers played a number of crucial roles, including (a) contextualizing the Super View as a cross-community knowledge space and developing a shared sense of the purpose and structure of the Journey of Thinking, (b) supporting student reading and creation of Journey of Thinking by scaffolding deep inquiry and reflection and monitoring the progress of each classroom to identify areas of inquiry with productive knowledge advances, and (c) facilitating cross-classroom interactions and the related extended conversations within each classroom to reflect on the insights, build connections, and put the knowledge together to explain difficult issues.
CHAPTER 6 STUDY 2

Classroom Context and Design

The study 2, the learning unit changed according to NGSS and the school district’s science curriculum arrangement. It started with the ecology unit which lasted for three months (2017 Sep-2017 Dec), and was followed by the human body section which lasted for six months (2018 Jan-2018 Jun). Study 2 only focused on the human body unit. Same as study 1, all classrooms continued to have high speed WiFi coverage. Each student has one laptop to use during the science class. Various human body models were provided in the classroom. Books of each human body system were displayed on the classroom shelf for students to readily access. Each classroom has half of the area for students to sit on their desk, and a big rug which allows students to gather together to have their metacognitive meetings (Figure 15). Based on Study 1’s results and experiences, the researcher updated the research results with the ITM team, as the ITM teach revised and updated Idea Thread Mapper software accordingly, the researcher conducted the second iteration by only using Idea Thread Mapper as the online interaction platform.

Figure 15. During the metacognitive meeting, students sit in the rug and share their learning, build-on each others’ ideas, and advance the community’s knowledge together.
Classroom Settings

In study 2, all classroom had high speed WiFi coverage. Each student has one laptop to use during the science class. Other supportive graphs, for instance, inquiry cycle, concept map, and metacognitive roles were also hang on the walls to intensify the classroom KB culture based on this year’s students’ reflection and discussion. Models and books were displayed on the classroom shelf for students to readily access. Moreover, students were introduced to the school library resources website to browse more E-books online.

Teacher Participants

The two teachers mentioned in study 1 continued their teaching in study 2. As they became more experienced in KB pedagogy and with more accumulated knowledge about the human body systems, they both became more confident in terms of offering students needed resources and facilitation. They were more creative in organizing their metacognitive meetings and other related learning activities.

In study 2, the teacher meeting was held once a month. During the meeting, teachers reflected on students’ Knowledge Building activities, made changes according to the students’ current understandings, monitored community progress and made short-term plans to extend students’ Knowledge Building activities. All of these meetings were recorded.

Student Participants

In study 2, there were 89 students from four classrooms involved in the study. There were 44 boys and 45 girls. Demographically, the 5th grade is more than 91% European-American, and 9% Asian-American, African-American, and Americans of Middle Eastern descent. Students were also all familiar with computer operations, and each had one computer to use during the science research time. They were all experienced with computer operation, as they had been
using a laptop since kindergarten. They were all able to access high-speed WiFi. For students who had disabilities, relative learning supports were provided, such as Google voice and accessible reading materials.

**Consent Forms**

Consent forms were administered as described in Chapter 5.

**Research Design: A Multiple-Level Interaction in Study 2**

In Study 2, similar with the first year, this study started with kick-off activities which involved several main human body systems. For instance, students ate apples and analyzed which human body organs were involved in the apple eating processes. Also students did high-kicks for one minute and measured their heart beats before and after the experiences which brought their awareness of the respiratory system and circulatory systems (Figure 16).

![Figure 16](image)

*Figure 16.* Students were eating apples and writing down their initial thoughts and inquiries of the digestive systems in the beginning of the unit during kick-off activities.
After the kick-off activities, students generated initial research questions based on their curiosities and formed into small groups based on the same research interest and conducted deeper research (Figure 17)

*Figure 17. Students generated their inquiry questions and formed initial wondering areas in the beginning of the unit.*

Each sticker stands for one student’s inquiry questions. Inquiries were grouped together based on their similarly. The exact same wondering areas were created on ITM at the same time by the teachers. As progress was made, students worked on the various areas and started to review and synthesize fruitful threads of inquiry emerging from their discourse. They further generated a group Journey of Thinking that can be shared as boundary objects to enable cross-community interaction.

Study 2 tested a number of improvements to the cross-classroom interaction design, including more efficient methods of Journey of Thinking writing process, which enables each student to access software and have a chance to write the reflection, and a cross-classroom collaboration working space -- Super Talk, which enables students from four classes working together to solve the challenging research question over one month. In study 2, students fully used the newly designed Journey of Thinking interaction page. What’s more, with the support of
the updated ITM, students co-identified core learning objects addressed by their collective discourse (Figure 18). As the learning progressed, students generated more wondering areas and the new wondering areas were added on ITM accordingly.

Figure 18. Example of students wondering areas on ITM in the beginning of the learning unit (Left) and the wondering added at the end of the unit (Right)

The discourse entries posted in an open online space as a thread based on the creation timelines, students are able to build on each other’s idea by using the build-on button, which creates a link between two threads to illustrate the connection over time (Figure 19). The continuation of the thread and links represent the idea improvement over time.

Figure 19. An example of students ITM wondering area, the red notes stand for each thread, the line stand for the function of “build-on” notes.
Each idea thread has a Journey of Thinking synthesis (Figure 20). After students accumulate sufficient knowledge in their own wondering areas, students can create their Journey of Thinking by reviewing their idea progress in the thread and co-author/update the Journey of Thinking synthesis. Students from another community or another learning group can use the synthseses of idea threads to view into the discussions and understand the progress of others’ inquiry learning. In line with the focus of Knowledge Building on continual idea improvement through progressive problem solving (Scardamalia & Bereiter, 2006), this Journey of Thinking can be further edited and then shared on the platform to be viewed by all other classrooms.

Figure 20. In each wondering area, there is a Journey of Thinking function. After students accumulated numerous information in their area, they can start to write their group Journey of Thinking.

After students posted their Journey of Thinking in the cross-community space, students have two ways to browse other classrooms’ Journey of Thinking. First, in the cross-community space, students can use the “Show wondering Areas and Idea threads” button, to have a bird’s
eye view of the overall wondering inquiries, and then they can further click on the round blue icon which leads them to the home page and view of the Journey of Thinking directly (Figure 21).

Figure 21. The “Show wondering Areas and Idea threads” function in the cross-community space enables students to have a bird’s eye view of other communities’ wondering areas. By clicking each round blue icon above the title, it will link to the focal page.

The second way of viewing Journey of Thinking is through a keyword. In the new design, there is a new cross-community space, with a search function, students can find all the related Journey of Thinking entries that contain the keyword (Figure 22). To further facilitate students’ cross-community collaborations, the new design in Study 2 enables students to generate a Super Talk -- an overarching question for the whole 5th grade to answer. Students from different classrooms and different topics work together to answer the challenging question
collaboratively. At the end of the whole learning unit, students had a metacognitive meeting which connects the Super Talk back to the home class and triggers students’ deeper discussion about the human body systems.

![Image](image_url)

**Figure 22.** The keyword function in the cross-community space enables students to find the relative Journey of Thinking synthesis quickly, the keywords are also highlighted in the context.

**Research Questions**

Rooted in design-based research method and Knowledge Building theory, based on a new online cross-classroom interaction learning environment, Idea Thread Mapper revised students Journey of Thinking generation process and enabled students to engage in cross-community interaction synchronically in a multi-level emergence approach.

Study 2 asked:

(a) What characterizes the quality and nature of the “boundary object” generated by the students?
(b) What kind of cross-community interaction occurs mediated by the synthetic boundary objects and how do students perceive the “boundary object” learning process?

(c) How does the cross-community collaboration affect the inquiry work in each home classroom?

(d) What role do the teachers play in facilitating cross-community interaction?

Data Sources

There are seven primary data sources for this study: a) students’ Journey of Thinking; b) students’ regular notes on ITM; c) class observation videos; d) Students and teachers’ interview transcriptions, e) metacognitive meetings’ videos and transcriptions f) the authors’ field notes during classroom observations, g) Students notes posted in the Super Talk view on ITM.

a) The Journey of Thinking: Students’ reflection continued facilitated by four scaffolds: “Our research question,” “We used to think,” “Now we understand,” “We further need to know.” In study 2: based on the first years’ experience, the Journey of Thinking writing process was redesigned, and the updated technology of ITM was added, which allowed each student a chance to write their reflections and then merge to a group Journey of Thinking. In other words, in each research topic group, each student can write individual reflections ongoingly as they making learning progress, and by using the built-in function “merge” in ITM, all student individuals’ notes will be combined into one group and then posted in the public area that can be accessed by all four classroom students (Figure 5).

b) Students’ regular notes on ITM: Starting from the beginning of the learning unit, students were introduced to share their information on ITM. Students first were introduced how to write a regular note on ITM, and get familiar with the interfaces. A regular note records students’ new learning, shares resources like pictures, videos, gifs and their ideas. More
importantly, the regular note on ITM enables students to continue their online conversation and learning outside of the science classroom. The “build-on” function in ITM enables students to connect one’s idea to others’, add new insights, critique, and ask questions.

c) Class observation videos: To capture how students and teachers interact with Journey of Thinking at school, the researcher set up a camera in the back of the class to record the class procedures. For students who do not have their parents’ consent to be videotaped or who do not want to be videotaped, their seats were arranged out of the camera’s view to avoid their images being captured. For small group activities, the researcher added more cameras.

In study 2, the researcher recorded 108 videos, each lasts 30-60 minutes. These videos were further divided and selected based on students’ cross-classroom interactions, for instance, students’ metacognitive meetings that discuss the Journey of Thinking generation process and what information they read from other’s Journey of Thinking, as well as regular classroom videos involving teachers’ facilitation of the cross-classroom interactions. All the videos have been saved in a safe place with lock and passwords. When the situation is needed, for instance, multi-group discussion, cross-classroom interaction, the author utilized extra audio-recorders to make sure capture the classroom activity at maximum.

d) Students and teachers’ interview transcriptions. 1) Students’ interviews: To understand students’ perceptions of cross-classroom interactions, a semi-constructed interview was conducted. In this procedure, only students who consented as participants in an interview were selected. The interview protocols were designed to capture the students’ learning experiences and their reflections on a deeper level. In study 2, the researcher chose 16 students who gave the consent form. Each interview took around 20-30 minutes. Students were taken to a quiet private classroom and had their Journey of Thinking open in a computer, and the whole
process was both videotaped and audiotaped. After the interview, the researcher transcribed all the video/audio and then put the transcripts into Nvivo12 for further quantitative analysis.

Teachers’ interviews: At the end of the school year, each teacher was interviewed around 30-40 minutes individually. The second year’s interview protocol was changed according to the changes of the multi-level research structure. The interview took place in their home classroom with a one-on-one, face-to-face setting. The interview used both video-recording and audio-recording at the same time. To fully engage in the conversation, interview notes were taken to record the highlight of the teacher’s reflections. After the interview, the researchers read and re-read the interview, and carefully transcribed the video files.

e) Metacognitive meetings’ videos and transcriptions. Each classroom held a metacognitive meeting around once every three weeks. Each metacognitive meeting lasted around 20-30 minutes. The metacognitive meeting has two forms, where the meeting doesn’t have a specific topic and with specific research topics depending on the community’s needs. Students were encouraged to participate in the metacognitive meeting, but at the same time were required to keep certain metacognitive meeting rules, for instance, students can try to make connections and build on what the previous students said to have a continuous and smooth conversation.

f) The authors’ field notes: To trace students’ cross-classroom activities, the author revised the observation form which enables the researcher to capture both students focal inquiry learning as well as the cross-classroom interactions. On one side of the field note was printed all students’ names; on the other side space was left to record students’ cross-classroom interactions.

g) Students’ notes posted in the Super Talk view on ITM. Besides the regular views on ITM where students from one classroom can only read their own classmates’ notes. The
Super Talk serves as a public view that enables all participants in the fifth grade to solve challenging questions together beyond their classroom walls. Moreover, this higher-social structure enables students’ interaction in a synchronic approach. In study 2, the Super Talk was added in the last month of the learning unit and lasted for one month. It has a challenging question “How do people grow?”

Data Analysis

**Grounded theory**: Grounded theory was employed as described in Chapter 5.

**Content analysis**: To examine the nature and quality of student Journey of Thinking writing, the researcher traced the Journey of Thinking created over time and conducted content analysis (Chi, 1997) to categorize the topics, nature of questions (e.g. general vs. specific, and types of information searched), the scientific levels (from pre-scientific to scientific), and complexity of ideas (from unelaborated facts to elaborated explanations) (Zhang et al., 2007). The coding schemes reflected the quality of students’ Journey of Thinking.

**Social network analysis of Knowledge Building discourse**: 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.” By using the Knowledge Building discourse network analysis tool-KBDex (Oshima, Oshima & Matsuzawa, 2012), the author compared the betweenness centrality of the critical concepts, which shows which concepts act as ‘bridges’ between concepts in a network.

To understand how the teacher facilitated this year’s cross-classroom interaction, the researcher used the metacognitive discourse transcriptions. By applying the coding scheme (Zhang et al., 2019), the teacher’s role in facilitating the cross-classroom interaction revealed a
specific pattern explained below. The researcher also applied discourse analysis to classroom metacognitive meetings. This study focuses on the how students’ interactions with the Journey of Thinking, what kind of information they learned from Super Talk collaboration, and what information they bring back to the home class.

Results

a) What characterizes the Journey of Thinking and how did students generate the Journey of Thinking to reflect on inquiry processes for cross-community sharing?

Students engaged in kick-off activities eliciting 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 Journey of Thinking function in the updated ITM. Focusing on each area of inquiry, students added reflections on their research individually, and then compiled the reflection entries into whole group Journey of Thinking (Figure 23). The syntheses of Journey of Thinking were then shared with all the other classrooms in the cross-classroom sharing space.

Students used the new inserted word cloud function to quickly check the keywords in each Journey of Thinking, the word cloud function brings attention to the highest frequency words in each reflection synthesis.
To examine the quality of student reflection in the Journeys of Thinking, researchers coded student ideas summarized under “We used to think” and “Now we understand” based on scientific sophistication and epistemic complexity (Zhang et al., 2007) (see Table 6). Ideas summarized under “Now we understand” show a high level of scientific quality and complexity. Compared with the previous year of this design-based research in which we tested a similar design without ITM. The Journey of Thinking syntheses had more words on average (362.3 versus 170.8 words), and the ideas summarized under “Now we understand” are more scientific and complex, suggesting improvement to student reflective inquiry. Moreover, 16% of
students updated their Journey of Thinking one month later; among them, 83% of students further investigated the last section of Journey of Thinking, and provided deeper insights into that research area.

Table 6
Comparison of coding of ideas in the Journey of Thinking summarized under “We used to think” and “Now we understand.” between 2017 and 2018.

<table>
<thead>
<tr>
<th>Journey of Thinking</th>
<th>2018</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>We used to think</td>
<td>Now we Understand</td>
</tr>
<tr>
<td><strong>Scientific Sophistication</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-scientific</td>
<td>33%</td>
<td>0%</td>
</tr>
<tr>
<td>Hybrid</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Basic</td>
<td>16.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Scientific</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Epistemic Complexity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unelaborated Facts</td>
<td>83%</td>
<td>%</td>
</tr>
<tr>
<td>Elaborated Facts</td>
<td>0%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Unelaborated Explanations</td>
<td>16.7%</td>
<td>0%</td>
</tr>
<tr>
<td>Elaborated Explanations</td>
<td>0%</td>
<td>83.33%</td>
</tr>
</tbody>
</table>

b) What kind of cross-community interaction occurs mediated by the synthetic boundary objects? And how did students start cross-community collaboration through “super view”?

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 that 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 24).

![Figure 24. Students’ collective wondering areas about human body systems and the Super Talk area.](image)

In the following week, students from Class 3 first started to contribute knowledge about how the brain, bones and muscles grow drawn upon their knowledge about these body systems. The teachers then started to advertise the Super Talk question in other classrooms. Teachers read the notes already posted by Class 3, and discussed what counts 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 25).
Figure 25. 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 and “helped out” in answering the big question. 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 repairing damaged tissues and growing. And new detailed information about bones was expanded and explained by Student D from Class 2 who was studying bones, as he mentioned that “bone grows from cartilage, they
fuse and go through a process called ossification.” Later, his peer who studied the same topic built on this note and added a more detailed description 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).”

Towards 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 an essential 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 the organs are made of cells, and the way cells grow is from mitosis, and cell growth is how humans grow. He imported his note about mitosis from his home class view into the Super Talk, which was read by other students and triggered more in-depth 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.

(c) How does the cross-community collaboration affect the inquiry work in each home classroom?

After students wrote their Journal of Thinking, aligning with the Super Talk collaboration on ITM, in each class, their inquiry activity continued. The teachers named the last month the
“Month of Connection,” and students extended their learning with the focus of the potential connections between different human body systems. After the reflection of their Journey of Thinking and cross-project reviews, teachers held metacognitive meetings and created bigger concept maps of how each organ connects to leverage their knowledge in their home classes.

During the metacognitive meeting about connections between different human body systems in the 5th month, students made substantial reflections, build-on, and had deep conversations about how various systems connect. 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 cell multiplication. The excerpt below shows how students from Class 3, which was taught by Teacher K, tried to understand collaboratively how and why the cell is the start and fundamental unit of human body systems and the connections between various systems. An excerpt from Class 3 in the 5th month’s metacognitive meeting discussed about human body systems:

Student K21: I think the cells in the immune system should be connected to cells that fight off the germs to fight cells.
Student K8: Actually the immune system is made up of cells.
Teacher K: What else is made up of cells?
Student K8: Blood K5: Isn't it everything?
Student K8: Yeah, well everything is made up of cells.
Student K5: Well there are all different kinds of cells
Teacher K: Ah uh!
Student K1: Yeah, but everything is made up of cells.
Student K8: It's the beginning of everything.
Student 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 are 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?
Student K12: I know something about cells, 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)?
Student K1: Yeah, so we grow taller just by cells growing in our body.
Student K5: ...and then it just multiplies, 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.
Student K15: I think cells are connected to the growth. because as you grow more cells in your body...
Teacher K: Every kind of cell...
Student K15: If you get a lot of cells in your body at one type, that's how we grow 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?
Student K10: Genes and heredity
Student K8: So the immune system is connected to the digestive system, skin, eyes.
Teacher K: Really? Tell us why?
Student K8: So, it is connected to skin cause skin is actually one huge defense against pathogens.

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 (see the following excerpt for an example).

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.
Student K5: When you run out of brain cells you die?
Student 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?
Student K7: Mitosis?
Student K5: DNA?
Teacher K: Oh, Mitosis? what about DNA? what's that related to?
Student K5: DNA and RNA.
Teacher K: What is that related to?
Student K8: RNA It’s just half of DNA.
Student 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?
Student K1: The DNA
Student K2: Chromosomes
Teacher: DNA and Chromosomes, and what can you tell us about heredity or DNA
Student K1: Hair color, eye color.
Student 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 Journey of Thinking Using the network analysis tool KBdex (Oshima, Oshima & Matsuzawa, 2012). The author compared the betweenness centrality of the critical concepts, which shows which ideas 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 Journey of Thinking activity, the concept of “Cell” had the highest gain in betweenness centrality (Figure 27). 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 27. Betweenness centrality of the key concepts discussed in the metacognitive meeting before (Above) and after the “Super Talk” meeting (Below).*
(d) What role do the teachers play in facilitating cross-community interaction?

After a month’s study under the guiding question of “How does the food digest?”, the digestive system group consistently understood the parts of digestive system organs and the process of the digestion. After posting these new ideas on the Idea Thread Mapper software, the teachers traced and noticed their learning progress. Before the metacognitive meeting, two members found an experiment of showing two kinds of digestion -- chemical digestion and mechanical digestion -- by watching an educational video and felt more motivated to share it with the class, so they asked the teacher whether they can share the experiment. The teacher asked them several guiding questions to make sure they really understand the topic and helped them to think a little bit deeper for the next step and prepared the materials for the demonstration. The teacher then invited the whole class to read notes that were posted under the digestive systems view on ITM to have some background knowledge before the discussion. Then the two students were invited to open the metacognitive meeting by using their experiment (Figure 28).

Figure 28. After the teacher guided students’ reading on ITM notes, students from the digestive system group brought an experiment chemical and mechanical digestion, to share in their metacognitive meetings
At the beginning of the learning unit, teachers encouraged students to bring in their notebooks to the metacognitive meetings to write down valuable information from their discussion. However, after the research and the teacher analyzed their notebooks, we found that students had a difficult time to write down complex scientific vocabulary. Students needed to take extra time, often misspelled, and got distracted due to the complexity and confusing situation. As a result, the teacher prepared a white chart of paper to let students write the critical scientific words before metacognitive meetings, so students from other groups can focus on the sharing and discussion, also were able to write down the new scientific words correctly (Figure 29).

![Figure 29. Blood group students are sharing their experiments with the topic of blood types, they wrote down their key scenic words and hang on an easel before the metacognitive meeting](image)

To understand how the teacher facilitates the cross-classroom interaction, the researcher applied a new set of metacognitive meeting coding schemes (Zhang et al. 2019).

The metacognitive meeting has many formats and has been held to address different questions under different circumstances; for instance, at the beginning of the semester, the metacognitive meetings were held with specific themes. Towards the end of the semester, the metacognitive meetings tended to focus on connections between various expert areas. Through
the qualitative analysis of the video recordings of the metacognitive meetings, the researcher found several the main patterns of how the teachers facilitate the metacognitive meetings to deepen students’ conversation in idea advancement. For instance, the following excerpt is from one teacher’s metacognitive meeting at the end of the semester (see Table 7). At the beginning of the metacognitive meeting, the teacher first directed the discussion by highlighting the main concepts and then open up the conversation by giving students change to share. In the middle of the conversation, instead of offering the knowledge directly, the teacher deepened the conversation by continually asking update questions for clarification and explanation. The teacher invited other students to join the conversation to contribute their knowledge to the focal research question and gave positive feedbacks and confirmation. Finally, the teachers ended up the conversation by summarizing the information that students mentioned, encouraged students to reflect their learning experiences.

Table 7
Excerpt of Teacher’s role in a metacognitive meeting

<table>
<thead>
<tr>
<th>Transcription</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher K: So you guys come up with a great question with super talk. How do we grow, and I feel like connections were made with other classrooms which are really terrific, maybe we learned something from the other classrooms. Was it N (student) that said what J (student) posted was really informative? If you ask that question how would you answer it?</td>
</tr>
<tr>
<td>…</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct the discussion topic by highlighting the main concept of discussion topic</td>
</tr>
<tr>
<td>Encourage students to participate</td>
</tr>
</tbody>
</table>
Teacher K: So could the hormones be bringing messages to the muscles?
Teacher K: Do we have water in our muscles? Do we have blood going to the muscles?
Teacher K: Do you think you need sleep to grow?
All: Yes
Student K: And that's mostly when the growth-pains happen.
Teacher K: Is that the only thing we need to grow?
…
Teacher K: You don't think that's what the hormone does?
Student T: I think the hormone is just like it said, it mostly just goes into the bloodstream, just as a messenger, I don't think, that's pretty much...
…
Student M: Yeah, everything is made of cells,
Teacher K: Everything is made of cells, give me a thumb up if you agree with M.
…
Teacher K: What are chromosomes related to?
Student E: Mitosis?
Student I: DNA?
Teacher K: Oh, Mitosis? what DNA? what's that related to?

Teacher K: So let's say you are studying bones, and you are in four different classrooms, someone is studying bones in other classrooms, would you like to be able to talk to the kids in other classrooms?

Discussion

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 Journey of Thinking 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 the Super Talk. Students showed solid reflections in Journey of Thinking with the help of ITM compared 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).

To understand in what ways the cross-classroom leveraged more profound discourse in each classroom, the analysis of the classroom conversations (metacognitive meeting) revealed specific patterns by which students reflected on the idea flow from the cross-classroom space back to the home classroom to understanding how the human body systems work together

In study 2, with the updated ITM and revised Journey of Thinking writing processes, students showed a higher level of epistemic complexity, which can be explained by the new opportunity that each student got in writing their reflections, and the convenient display where the Journey of Thinking button was placed at the same view with the regular working space.

The analysis of the fourth research question about teachers’ role elaborated how teachers facilitated the metacognitive meeting sharing and cross-boundary interactions in detail.

As the teachers’ metacognitive meeting transcriptions showed, their teaching revealed specific patterns in facilitating the learning process. This pattern is as follows: a) the teacher always directs and redirects the discussion topic by highlighting the discussion topics, b) teachers deepen ideas by asking uptake questions, encouraging students to participate the conversation and revoicing students ideas, c) teachers confirm students’ contributions and make connections with other topics, and d) the teacher summarizes the whole metacognitive meeting by a summary and pointing out the future research directions reflected by the students.
CHAPTER 7: CONCLUSIONS AND IMPLICATIONS

To sum up, the results of this dissertation illustrated an elaborated account of how grade 5 students could work across the multi-level boundaries of different classrooms to engage in collaborative Knowledge Building focusing on authentic scientific inquiries. The results illustrated a multi-year, multi-level emergency interaction approach to sustain students’ Knowledge Building in both local and cross-community levels. The students’ frequency interactions in collaborative space, both in Super View in study 1 and the Super talk in study 2, show how the higher structure layer advanced the collaboration and extended interaction of the community’s knowledge at stake.

More specifically, within students’ home class, while students engaged in focal inquires and deepened their learning through knowledge building discourse, students accumulated insights from their ongoing inquiry and generated their Journey of Thinking. With sufficient time and choice, they created high-quality reflections on the areas that they understood. The Journey of Thinking subsequently served as the boundary object shared in the cross-community area that published local ideas to a higher social level.

The Super View in pilot study and study 1 provides a public space that allows students to read other classrooms idea syntheses even from the previous years. The Journey of Thinking with the same format facilitated the reading process productively. The high frequency of readings and posting of Journey of Thinking syntheses up-scaled students interaction from local to a higher social space. As students made connections with other members’ Journey of Thinking syntheses, the new insights and idea connections were further shared by the students back in the home class in connection with the needs of the local area. Those connections further enriched the
local discourse in providing materials and new insights to facilitate more comprehensive understandings.

The Super Talk in Study 2 revealed students’ needs in collaborating in a public space synchronically. As for the Super Talk functions as in study 2, based on the initial data results and challenges investigated in study 1, the researcher used the updated ITM which includes various interaction and analytics tools to continue the investigation of cross-community Knowledge Building in an international network of classrooms. Moreover, the new ongoing discussion view space in the higher social level provides interaction and offers an additional opportunity and dynamics for cross-classroom collaboration. When the current year’s students met challenging questions that could not be answered by their home classroom, the ongoing discussion public space provides a space where all the current years’ members can engage in solving the research question from different perspectives collaboratively. These interactions and knowledge build-on that extend beyond the classroom walls connect the current year’s students’ efforts and knowledge to pursue deeper inquiry work. Members who participated in the Super Talk discussion also shared the learning information back to the home class in connection with the local knowledge building needs to develop more coherent understandings. The data analysis results from study 2 illustrated how ITM better facilitated cross-classroom interaction and collaboration processes. The teachers’ new strategies to prepare the metacognitive meeting and cross-classroom interaction demonstrate their improvement in teaching KB pedagogy.

**Contribution of This Study**

Based on the results mentioned above, this dissertation shed light on the possible designs and processes to enable collaborative knowledge building across a network of classrooms in a broader learning environment and ongoing learning process. The findings elaborated a multi-
level, emergent interaction approach to supporting student knowledge building in their local and cross-community spaces over an extended period.

The results have several implications for conceptualizing and designing learning space for sustained Knowledge Building across communities. First, it is crucial to approach collective knowledge space as an essential component of learning space design for learning communities. Collective knowledge space rises above other physical aspects of learning space, with ideas generated in various physical activity settings selectively objectified as knowledge artifacts living in the collective knowledge spaces as the focus of continual discourse and cognitive interactions.

Second, the results of this study further demonstrate the possibility to extend the design of collective knowledge space to include a cross-community layer. While the local knowledge space of each community supports students’ ongoing inquiry and micro-level idea interaction daily, the cross-community knowledge space supports higher, macro-level interactions focusing on major progress worthwhile for sharing with other communities. The progress can be shared by creating synthetic artifacts that document the Journey of Thinking, which serve as boundary objects to leverage students’ mutual learning, idea connection, and build-on across communities. Third, the findings of ongoing cross-community space suggest a promising research design to increase the multi-level interaction dynamics. By accumulating current years members’ insights synchronically in addressing challenge questions, the collaboration from the micro-level advanced the idea of diversity in the macro-level, the discussion results further provide learning materials at the micro-level idea interactions.
Limitations for Practice

One limitation of this study is that the sample size is still relatively small. Only 229 students participated in this study; student participants were all from grade 5. As the age might affect students’ cognitive understandings and self-efficacy in the learning settings, a different age group or larger classroom size may have a different inquiry learning experience and social interactions in their science learning from what is described in this dissertation.

The number of teachers (four teachers in total) who participated in this study both in the pilot study and study 1 and study 2 were familiar with the Knowledge Building pedagogy at the time when the data were collected. A different set of teachers or new teachers who use Knowledge Building pedagogy may have different Knowledge Building practices as mentioned in this study.

Future Research Directions

The abovementioned findings shed light on cross-community interaction and collaboration in Knowledge Building communities. The researcher will further investigate the cross-community collaboration phenomenon by using the newly updated Idea Thread Mapper which is equipped with ongoing semantic analytics tools, a revised cross-classroom sharing space named as “buddy classrooms”, and other visualisations analytics in both local and cross-community areas. Furthermore, with the upgraded technology, I also plan to explore the cross-country collaboration in broader social levels for educational empirical practices and transformation.
References


http://dx.doi.org/10.1016/j.compedu.2013.09.009


*International Education Studies*, 4(4), 118.


