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Give Student Ideas a Larger Stage: Support Cross-Community Interaction for Knowledge Building

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Abstract

This study explores boundary-crossing interaction between two grade 5/6 science classrooms that operated as knowledge building communities. The two classrooms studied human body systems with the support of the Knowledge Forum over a ten-week period. The knowledge building practice integrated student-driven inquiry and discourse within each community and cross-community interaction mediated through “super notes” posted in a cross-community meta-space. Students co-authored super notes as epistemic boundary objects, each of which synthesized knowledge progress in an emergent line of inquiry for cross-community sharing. Qualitative analyses of classroom videos, online discourse, and interviews provide a rich description of how the students conceived, generated, and interacted with the super notes for knowledge building. The processes to transcend student ideas toward the higher social levels for sharing through boundary-crossing further served as a larger context for idea development toward higher epistemic levels. Incorporating cross-community interaction is important for scaling CSCL-based classroom practices in a way that fosters high-level epistemic engagement.

Keywords: Cross-community interaction, Epistemic boundary objects, Knowledge building communities, Learning across levels, Rise above

Introduction

As a core contribution to the broader field of education, research on computer-supported collaborative learning (CSCL) has produced deep insights about how productive learning occurs in learning communities through students' joint inquiry and collaborative discourse, often with the support of collaborative technologies (Hod, Bielaczyc, & Ben-Zvi, 2018; Slotta, Suthers, & Roschelle, 2014). However, the existing research has focused on student collaboration in small groups and individual classrooms. It remains a largely unexplored opportunity to extend student collaboration and interaction to higher social levels, such as across different classrooms. This study tested a new approach to supporting cross-classroom interaction in two upper elementary science classrooms. The findings inform opportunities to extend collaborative knowledge building to a larger social context in which students' productive ideas can spread and interact across boundaries, leveraging high-level knowledge building.

Collaborative Interaction for Knowledge Building

CSCL programs engage students in collaborative discourse and interaction to solve problems, construct shared knowledge and deepen personal understandings. Among the CSCL programs, Knowledge Building pedagogy attempts to redesign classroom practices in line with how knowledge and ideas are processed in real-world knowledge-creating organizations (Scardamalia & Bereiter, 2006). Working as knowledge building communities, students generate and continually improve their ideas, which advances the "state of the art" of their community's knowledge. They identify and work on authentic problems of understanding, contribute their ideas to a public knowledge space as epistemic/conceptual artifacts (Bereiter, 2002), and engage in knowledge building discourse to improve their ideas in light of evidence and sources. An online environment—Knowledge Forum—was developed to support high-level knowledge processes (Scardamalia & Bereiter, 2006). Students create *views* (workspaces) in line with their knowledge goals, contribute ideas and questions by writing *notes* in the views, and build on and reference one another's notes for interactive discourse. The online discourse unfolds as part of students' social practices of working with knowledge (Hakkarainen, 2009), which integrate various inquiry activities involving individuals, flexible small groups and the whole class.

Extensive research has identified productive patterns of collaborative discourse in knowledge building communities and other problem-based, collaborative learning settings (e.g. Hakkarainen, 2003; Järvelä et al., 2016; Mercer & Littleton, 2007; van Aalst, 2009; Zhang et al., 2007). As a central theme, collaborative discourse for creative idea development entails not only *horizontal moves* to incorporate more topics, diverse ideas, and information sources but also *vertical moves* (Wegerif, 2013): to dig deeper into the underlying issues and problems as progress is made and "rise above" to higher planes of thinking and conceptualization. Scardamalia (2002) defines "rise-above" as a high-level knowledge building process and principle to work with the diversity, complexity and messiness of ideas, and out of that achieve new syntheses to formulate higher planes of explanations (e.g., theories or theory-like constructions), more inclusive principles, higher-level problems, and action plans. The conceptualizations achieved through such reflective moves may offer increasingly deeper and more coherent frameworks of thinking that can explain interrelated issues based on core fundamental principles. As a specific case, a class of fifth- and six-graders studying electricity first investigated various topics such as batteries, electrical circuit, and static electricity with the understanding of electricity as energy flow. A rise-above moment occurred when they moved from the focus on energy flow to the notion of electricity as electric charge carried by electrons. The higher-level conceptualization helped them explain a range of seemingly disconnected problems related to how battery, static electricity, and electric circuit work: “All are connected.” (Zhang et al., 2018).

Despite the advances in understanding collaborative discourse, the CSCL field still faces the challenge of enabling sustained inquiry and collaboration in broader classrooms for educational change (Wise & Schwarz, 2017). As a specific gap, existing research has focused on student collaboration in small groups and individual classrooms over relatively short periods of time. New advances are needed to understand how collaborative knowledge building can be sustained at higher social levels over longer timescales (Stahl, 2013). The current research seeks ways to enable students' collaborative interaction across different classrooms. With the extended social interaction, students gain the opportunity to conference with an expansive network of ideas, expertise, and people to pursue sustained inquiry and develop high-level understandings.

Toward a Larger Dynamic System View for Knowledge Building Across Social Levels

We review the literature from the broader fields of creativity and knowledge creation to understand how knowledge building interactions unfold across social levels. In real-world knowledge communities (e.g. innovators), members participate in collaborative interactions and dialogues over time, with interactive ideas continually building on one another revealing ever-deepening understandings, better solutions as well as emergent challenges and goals (Sawyer, 2007). The interactive process is characteristic of “collaborative emergence,” which refers to the mechanism by which collective phenomena and properties are collaboratively created by individuals, yet are not reducible to individual action (Sawyer, 2005). As a team member identifies a problem and contributes ideas, the fellow members actively listen and successively build on, giving rise to collective outcomes that cannot be attributed to any single individual (Dunbar, 1997; Miyake & Kirschner, 2014). The emergent, collective outcomes include epistemic products such as new/better theories or designs as well as shared social structures and resources through instrumentation, team forming/reforming, organizational capacity building, and field structuring (Zhang et al., 2018).

In the above context, knowledge building interactions unfold and extend across the emergent social levels, including *individuals* collaborating in *small groups* (organized or opportunistically formed) within each *organization/community*, which is further part of an *intellectual network (field)* that advances the collective knowledge of a domain (Csikszentmihalyi, 1999). The interactions at the different social levels share common practices while exhibiting unique patterns and functions. Members' ongoing discourse within each research team tends to be more exploratory, incremental, and distributed to continually generate and improve ideas through interactive processes (Dunbar, 1997). Discourse across teams in a research field focuses more on sharing and connecting major knowledge advances that have been achieved by various teams, involving more persuasion and argumentation that supports social review ("gatekeeping") of knowledge (Csikszentmihalyi, 1999). To contribute to the larger discourse in their field, members in each research team need to refine and transform their ideas toward higher epistemic levels to develop statements of ideas that are valuable and acceptable to the field (Latour & Woolgar, 1986). They need to climb the epistemic ladder in order to make a broader impact.

The multi-level system view highlights the role of the larger discourse in a shared field. A creative field leverages the work of various teams/communities and their members by accumulating a shared, easily accessible knowledge base represented using various inscription systems (e.g. papers) (Csikszentmihalyi, 1999) and further facilitating dynamic idea contact and cross-fertilization (Bielaczyc & Collins, 2006). The extended social interactions create a macro social context and infrastructure that shape and sustain the knowledge building work in each local community over time across generations. With a sense of the perspectives and norms in their field(s), knowledge builders not only dialogue with their immediate peers on site but also the views of others who are absent— the "superaddressee" (Bakhtin, 1986) who represents the voices and norms of the larger community.

The Design Challenge of Cross-Community Interaction

Research on CSCL needs to tap in the opportunity to give students ideas a larger stage by incorporating cross-classroom interaction. Limited literature exists alluding to the possibility of using online systems to build cross-classroom connections (Hawkes & Romiszowski, 2001; Reil, 1995). Stahl, Koschmann, and Suthers (2006) noted the potential use of the persistent record of interaction and collaboration as a sedimentary resource for knowledge building across social and temporal boundaries; but this possibility has rarely been investigated. Among the few explorations, researchers tested cross-classroom sharing of online discourse (Laferriere, Law, & Montané, 2012; Lai & Law, 2006) across international sites. Each of the participating classrooms gave the partner classrooms access to its online discourse space, so students could read the notes of the partner classrooms and respond. The cross-community collaboration led to productive classroom changes. However, difficulties arose for students to understand and build on other communities' extended online posts without a clear sense of the classroom contexts, such as the inquiry activities and histories that are essential to the knowledge practices of each community (Hakkarainen, 2009). New design approaches are needed to make knowledge progress accessible across classrooms and support interactions across the different social levels.

Our Approach to Cross-Community Knowledge Building

In light of the dynamic social systems view, this research proposes an emergent, multi-layer interaction approach to collaborative knowledge building across communities. Students' collaborative interaction unfolds across emergent social levels, which include the *local (home) knowledge space* of each classroom community and a *cross-community meta-space* shared with other classrooms. While members of each classroom work in their local discourse space to investigate various problems and deepen their understandings over time, they create rise-above syntheses to share major knowledge progress and challenges in the meta-space for cross-classroom interaction. The rise-above syntheses serve as boundary objects to bridge the different classrooms that pursue interconnected knowledge building efforts. Below we further unpack the components of this framework.

First, we approach cross-community interaction as an expansive social context for leveling up students' thinking and discourse toward higher epistemic levels. As the above-reviewed literature reveals, the social uprising and epistemic advancement of ideas are interconnected processes. As ideas transform toward the higher epistemic levels, they transcend to higher social levels for broader sharing and discourse across different teams and communities (cf. Csikszentmihalyi, 1999; Latour & Woolgar, 1986). Therefore, the purpose of cross-community interaction among students is not only to broaden idea sharing but also to leverage idea advancement toward increasingly higher levels of epistemic sophistication. Climbing the epistemic ladder, students' discussive interaction moves from sharing initial intuitive questions and speculative personal thoughts to contributing incremental testing, questioning and improvement of ideas; from describing facts to developing elaborated explanatory accounts supported by systematic findings; and connecting their knowledge to generate "big ideas," coherent understandings, as well as higher goals for further inquiry. The interactive discourse within each group and community supports exploratory and incremental moves for idea improvement, giving emergence to major knowledge advances over time. Conceptual advances that have emerged at the higher epistemic levels have a greater potential to benefit broader knowledge builders and add to the larger discourse that takes place across classrooms.

Thus, our design of student interaction integrates two emergent social levels, which include the *local (home) knowledge space* of each community and a *meta-space* shared across communities. Knowledge contributions to the meta-space focus on sharing high-level knowledge advances that have emerged from each classroom's progressive discourse within their home space. To make students' knowledge advances sharable and accessible, our design approach capitalizes on the power of *boundary objects*. Boundary objects are artifacts used to bridge the boundaries (discontinuities) between different social worlds (Star & Griesemer, 1989). Objects generated by a community often have contextual meanings that are not easily accessible or transparent to other communities. Boundary objects are effective for bridging different communities in that they offer "means of translation" with interpretative flexibility (Star & Griesemer, 1989): they have a structure that is common enough to make them recognizable and interpretable across the different social worlds and, at the same time, allows the participants to reinterpret and re-contextualize the meanings in relation to their own practice. Distributed online discourse entries lack the features of boundary objects. Therefore, this research explores having students create reflective syntheses of inquiry progress for cross-classroom sharing. Students and teachers call such syntheses "super notes," which are posted in the cross-classroom meta-space. Each super note offers a reflective rise-above view of a line of inquiry pursued by the members of a classroom, involving a series of discourse entries (notes) contributed over time to investigate a conceptual issue or problem. A set of reflective scaffolds (prompts) has been designed to support super note writing, including (a) Our inquiry topic and problems, (b) We used to think…now we understand… and (c) We need deeper research. These scaffolds can assist students to reflect on emergent inquiry directions and progress (Zhang et al., 2018). The shared use of the super note scaffolds may further provide the common structure needed for boundary crossing (Star & Griesemer, 1989).

Student cross-classroom interaction is mediated by super notes that work as boundary objects. Students share and read one another's super notes to understand the inquiry progress of the different classrooms and engage in extended interactions with the ideas gained from other classrooms in their further inquiry. As the literature on boundary crossing suggests, through working with boundary objects, participants can identify and reflect on the practices of the different communities; reframe and enrich their local understandings and practices, and potentially generate new, in-between practices that go beyond the existing practices (Akkerman & Bakker, 2011; Star, 2010).

Our Research

To explore and elaborate the above approach to cross-community knowledge building, we have been conducting a design-based research (Collins, Joseph, & Bielaczyc, 2004) project in a network of upper elementary science classrooms over multiple school years. A series of studies are embedded in this project. Each study addresses unique design challenges and research questions, such as how students approach, create and interact with super notes; how students integrate the local discourse space and the cross-community meta-space to support continual idea advancement; how ideas are transformed as they travel from a classroom's local discourse to the meta-space to meet broader knowledge builders; and how teachers orchestrate cross-community knowledge building with technology support (Yuan &

Zhang, 2019; Yuan, Zhang, & Chen, 2019). The study reported in the current paper explores how teachers and students approach super notes as boundary objects to support both conceptual advancement and cross-classroom sharing of ideas. Our research questions ask: (a) How did the teachers and students conceive the nature of super notes for knowledge building across communities? (b) What types of super notes were generated, through what classroom processes? And (c) in what ways did the students interact with the super notes from other communities to support their knowledge building?

Method

Participants and Classroom Contexts

This study tested cross-community interaction in two upper elementary classrooms each combining grade 5 and 6 students (10-to-12-year-olds) at a K-6 school at the Dr. Eric Jackman Institute of Child Study Laboratory School in Toronto, Canada. The two classrooms were taught by two teachers (Mr. B and Mr. M), respectively. Among them, Mr. B was more experienced with teaching science using knowledge building pedagogy and technology. Mr. M had five years of teaching experience but was relatively new to teaching science in grades 5/6. There was a total of 24 students in Mr. M's room and 23 students in Mr. B's room. The students had experience with knowledge building pedagogy and Knowledge Forum in their prior study in the lower grades.

Knowledge Building Design and Implementation

The two classrooms studied human body systems with the support of the Knowledge Forum platform over a ten-week period with two science lessons each week. With their teacher's support, students in each classroom generated interest-driven questions about the human body, put forth tentative ideas, tested and improved their ideas through experiments and observations. They engaged in critical reading of books and online materials and conducted knowledge building talks in small groups and as a whole class to share and build on one another's ideas. Extending their face-to-face interaction and discourse, students in each classroom contributed their ideas, questions, and findings on Knowledge Forum in their own classroom's views (workspaces), where they read and built on peers' ideas in the online discourse.

Cross-community interaction was supported through a view (workspace) on Knowledge Forum called the "Super View" where students accessed and posted super notes for cross-community sharing. A background image was added to the Super View to facilitate the sharing process: two trees each with branches where super notes about various inquiry topics could be placed (see Figure 1). Each classroom had its own "tree of knowledge," and students could take a look at their peer classroom's knowledge at any point of the knowledge building process. Prior to this study, a set of classrooms from two schools had engaged in knowledge building about human body systems and created reflective syntheses of their idea progress. Based on these syntheses, an initial set of super notes was posted to the Super View, each organized using three scaffolds: namely, *Our research topic and problems*, *We used to think…Now we understand…*, *We need deeper research*.

<Insert Figure 1 about here>

The researchers and teachers co-designed the overarching process of cross-classroom collaboration in the human body science inquiry without creating scripted lessons. Each of the two teachers then worked out his own classroom procedures based on students' progress and input, with ongoing information sharing to keep each other updated. Each classroom first introduced the Super View in the third week of the human body inquiry when their students had generated their own questions and conducted initial inquiry. Students read the super notes from the previous classes and reflected on what they could learn from the questions and ideas. With deeper inquiry conducted in each classroom in the next three weeks, students working on various themes started to create super notes to summarize their progress for sharing with their own classmates as well as with the other classroom. A total of 16 super notes were created, including ten from Mr. B's classroom and six from Mr. M's classroom. Students from the two classrooms were given the time to read the super notes individually based on their interest. A whole class meeting was organized in each room for students to discuss what they had learned from the super notes.

Data Sources and Analyses

The data sources included classroom observations of each science lesson, video recordings of classroom discussions, online discourse in each classroom's regular views and the shared Super View, and student and teacher interviews. A researcher observed the science lessons and took detailed notes. The video records and related observation notes captured major classroom episodes in which students were introduced to the Super View, discussed information learned from the super notes of the other classroom, and created super notes based on their own work for cross-classroom sharing. At the end of the science inquiry, we conducted a semi-structured interview with each of the two teachers using approximately 45 minutes. The teachers were asked how the cross-community interaction helped their students and how they facilitated such interactions. We also interviewed a total of 13 individual students, who showed various levels of participation in the knowledge building process and had agreed to be interviewed. The interview questions asked the students to reflect on how super notes were different from regular notes, how they decided what specific ideas should be included in their super notes, and how reading the super notes of other classrooms was helpful or not for their knowledge building. The interviews were video-recorded and transcribed for analysis.

To understand how the students conceived the nature of super notes for cross-classroom sharing, two researchers analyzed the interview data following procedures of grounded theory analysis (Strauss & Corbin, 1998). They individually read and re-read the transcriptions of the interviews, created open codes, and clustered the open codes into primary themes to capture prominent patterns. The researchers then congregated their codes through co-reviewing the open codes, initial themes and examples from data; merging the common codes and themes; and discussing the unique codes from each coder to weigh in their meanings and relevancy. A set of themes was developed to capture student conceptions about the super notes (see Results). The themes were further validated through checking coded data against the themes, and connecting the themes identified from student and teacher data.

To investigate students' reflective and epistemic efforts to generate rise-above syntheses for cross-classroom sharing, we applied content analysis (Chi, 1997) to examine the epistemic quality of students' super notes and conducted qualitative analysis of classroom videos and observation notes to understand the reflective processes that had led to the super note creation. The content analysis of the super notes focused on coding major problems of inquiry and insights gained. Drawing upon prior studies (e.g. Tao & Zhang, 2018; Zhang et al., 2007), each super note was coded based on (a) inquiry topic addressed, (b) the types of inquiry questions including specific fact-seeking questions versus deeper, explanation-seeking questions to elaborate the functions, mechanisms, and connections of the human body systems, and (c) the depth of understanding achieved as gauged using two four-point scales, including scientific sophistication (1-pre-scientific, 2-hybrid mixing scientific information with intuitive understandings, 3-basically scientific, and 4-scientific) and epistemic complexity (1-unelaborated facts, 2-elaborated facts, 3-unelaborated explanations, and 4-elaborated explanations). This coding framework was tested in our prior study (Yuan & Zhang, 2019), with an inter-rater reliability of 93%(percentage of agreement). To further look into the connection between students' super notes and their ongoing discourse in their regular Knowledge Forum views, we also used the list of super note topics to code students' regular notes. Two coders independently coded 81 notes (22% of the total notes), resulting in an inter-rater agreement of 98% (percentage of agreement).

To further understand the reflective processes by which the students generated super notes with the support of their teacher, we analyzed our classroom observation records and videos to trace the temporal process by which students in the two classrooms synthesized their inquiry progress, complemented by the student and teacher interviews. Using a narrative approach to video analysis (Derry et al., 2010), a researcher (classroom observer) first browsed the videos and transcriptions to develop an overall sense of the processes by which the teachers introduced students to the Super View and facilitated their generation of super notes as well as the follow-up reading and discussions. This was followed by the identification of "digestible" chunks in the videos representing the major activities. These chunks of videos were indexed based on activity themes and time sequence. Focused analysis was conducted for each episode to identify the reflective processes of the students with the teacher's specific input, focusing on their moves to identify productive themes of inquiry from members' diverse discourse contributions and to synthesize major progress of understandings out of the specific ideas and information generated in each line (theme) of inquiry.

To address the third research question about how students interacted with one another's super notes and built social connections, we retrieved data from the Knowledge Forum that traced who had read whose super notes and applied social network analysis (Wasserman & Faust, 1994) to gauge the density and patterns of social ties. We also analyzed the video records and transcriptions of classroom discussions in which students shared what they had learned from the super notes. These were complemented with qualitative analysis of student interviews in which they reflected on how the super notes helped their knowledge building.

Results

How did the students and teachers conceive the nature of super notes?

Qualitative analysis of student interviews revealed interrelated themes about how the students conceived the nature of the super notes in comparison to their regular notes posted in the ongoing online discourse. Table 1 shows the five main themes representing students' conceptions.

<Insert Table 1 about here>

Themes 1-2 characterize student notions of the epistemic role of super notes, including rising above toward "big ideas" and foundational knowledge and reflecting on the journey and process of inquiry. Students commented that super notes should "focus on the entire idea…not just the tiny details." So the students needed to review all their ideas and bring forth the core concepts and "big ideas" of value to their community and beyond. Students used super notes to further reflect on their journey of inquiry to co-investigate various topics and problems, supported by the super note scaffolds. Themes 3-5 show student understandings of super notes as a means to sharing knowledge advances with broader knowledge builders. Students positioned super notes as for giving knowledge to others

(Theme 3). While regular notes in the online discourse focus on interactive responses to one another, super notes help to consolidate their knowledge advances for others to know. As a student commented, the super note "really helps explain what you researched a lot about to other people who don't know a lot about what you've been researching." To share knowledge with the broader audience, students further recognized the need for their super notes to be accountable (Theme 4) and accessible (Theme 5). Super notes should present well-developed and refined knowledge achieved through solid inquiry, because "you do not want to misinform everybody." The ideas in super notes need to be well-phrased and clear, with enough but not too much detail.

Aligned with the students' conceptions, the analysis of the teacher interviews and classroom videos showed that both teachers conceived and presented the "Super View" as a higher-level space of discourse where students formulated major questions and "big ideas" for cross-community sharing. Cross-community sharing of knowledge advances gave students a reason to write the super notes, allowing students' ideas to have a chance to meet a broader audience. Unlike regular Knowledge Forum notes, the super notes needed an additional level of reflection and refinement; both teachers asked students to show them the final draft of their super notes before posting to the Super View. They emphasized that the super notes were about sharing the "journey of thinking" rather than communicating specific information. The goal was to show how their understanding and thinking had evolved during the course of the inquiry. Therefore, the super notes were meant to offer a metacognitive view of their inquiry. The teachers commented that the super note scaffolds played a crucial role in making this metacognitive layer visible by framing the process of thinking from "what you used to think" to "what you understand right now" with "an eye on helping someone." While both teachers emphasized using the scaffolds as a way to structure the super note, Mr.

B underlined the importance of clarity, so the super notes could be understood by students from a different classroom who lacked the knowledge about the classroom contexts. For Mr. M, the super note was about pulling out the important ideas from their regular Knowledge Forum views and bringing together “important points or discoveries that everybody should know about.”

What types of super notes were generated, through what processes?

We analyzed the topics of the super notes generated by the students in connection with their regular notes in each classroom’s online discourse. Figure 2 shows the topics of the super notes created by the two classrooms and the number of regular Knowledge Forum notes posted related to each topic. Mr. B’s students created a total of ten and Mr. M’s students created six super notes. Their super notes addressed both shared topics of inquiry as well as topics unique to each classroom (e.g., genes and DNA in Mr. B’s classroom). While some of the super note topics had intensive discussions in the Knowledge Forum, a few other topics had only been addressed by very few regular notes. These topics were very specialized (e.g., allergies, heart stroke, and the emotion of being scared) but were identified as interesting and helpful for other students. Another related factor, according to the teachers, was that some of the inquiry work was documented in students’ personal notebooks and shared face-to-face, therefore not all were reflected on the Knowledge Forum.

<Insert Figure 2 about here>

We conducted content analysis to examine the questions and ideas synthesized in the super notes. In the 16 super notes generated, students identified 32 questions for deeper inquiry. Most of the questions (n = 28) are explanation-seeking questions searching for reasons, mechanisms, and connections (e.g., what are the nerves actually doing when they react?) as opposed to factual questions (*n* = 4). As noted before, students used the scaffolds of "we used to think…" and "now we understand…" to summarize their idea progress in each super note. We coded student ideas summarized under the two scaffolds based on epistemic complexity and scientific quality. As Table 2 shows, students' knowledge advances synthesized under "now we understand…" show a high level of scientific quality focused on offering elaborated explanations of how things work. These updated understandings are dramatically different from students' initial ideas summarized under "we used to think…" which included more pre-scientific thoughts and simple facts about the human body.

<Insert Table 2 about here>

The analyses of classroom videos and interviews revealed actual processes by which students worked on the Super View and created the super notes with their teacher's support. The specific processes are elaborated below.

(a) Navigating the Super View and reading existing super notes. During the third week of the human body inquiry, the teacher in each classroom introduced his students to the Super View (see Figure 1) and showed the existing super notes created based on the previous classrooms that had studied the same science topic. Both teachers explained the Super View as a place where the summaries of "big ideas" from different classrooms could be shared. Mr. M particularly referred to the background image with two trees, using the analogy that the different branches of the tree would represent different "big ideas." The teacher in each classroom opened a super note as an example, pointing out the scaffolds used: Start with "we used to think", and continue with "now we understand", and finish with "we need deeper research." Mr. B facilitated a brief reflective discussion about the writing style of super note by asking: "When writing a summary, would you want to put ANY detail of your research?" Students responded "No," adding that with too many details their peer students would get bored and confused. They noted that a super note is a high-level overview: It's like asking the person doing the research, "what have you done?"

(b) Whole class discussion to identify high-potential areas of inquiry. Following the introduction of the Super View, each classroom held a reflective conversation in which students identified the various areas of inquiry related to the human body systems and reviewed their knowledge advances. Students reflected on their inquiry work with the intent to possibly create a super note for each productive "juicy" area of inquiry. The teacher recorded the major areas of inquiry mentioned by students. Mr. B's students identified the heart's reaction to stressful situations, genes and DNA, puberty, spine and spinal cord, eyes, brain, sleep, while Mr. M's students identified high-interest areas related to healing, memory and learning, brain and brain damage. Based on the shared areas of interests, students formed flexible groups to deepen their inquiry as needed and co-write super notes. Students in both classes were encouraged to identify additional "juicy" areas of inquiry as their work proceeded and form new groups to write super notes.

(c) Small-group review of inquiry progress in each area. Following the whole class discussion, students in each small group sat together to discuss what they had learned about their focal area of inquiry. Prior to the super note intervention, students had written notes in their regular Knowledge Forum views to share specific questions and ideas, explore information from authoritative sources (e.g. books, videos), and discuss findings from experiments. Students had also been taking personal notes about their research. The teacher encouraged the students in each group to review their online posts and personal notes as a way to start their drafts of the super notes. During the small-group reflection time, the teacher walked between groups to listen to students' thoughts, offered input to help clarify their ideas and questions, suggested resources that they might use to do deeper research, and gave guidance on how they might collaborate on the super notes. For instance, in the group focusing on DNA, four students first updated their personal notes taken in MS Word and shared their documents by passing around each other's computer. Summarizing four separate long documents was challenging, so Mr. B, noticing the challenge, approached the group and suggested that they choose one person to type the draft of their super note.

(d) Deepening research to refine knowledge as groups and individuals. Reviewing and analyzing existing work and ideas, students noticed questions and issues that needed to be better understood. For example, a girl in Mr. M's room working on a super note about eyes attempted to figure out what role nerves play in the eye and what would happen if the nerves were disconnected from the brain. These issues pushed the students to conduct further research using information from books and websites. Some of the sources were beyond the students' reading level. The teacher worked as a co-learner and helper to interpret the information, explain scientific terms, and model rephrasing ideas using simpler terms. When making use of the sources, students were not simply finding individual, isolated facts, but trying to explain certain processes and inform others about the "big ideas." Therefore, they looked for credible information and connections that would allow them to explain complex phenomena and processes, working across sources to check on the consistency.

(e) Selecting and synthesizing important ideas to formulate coherent understandings and "big ideas." In light of the diverse ideas reviewed, students in each group worked together to formulate conceptual understandings to be included in their super note. The analysis of the interviews identified a number of criteria that the students had in mind for their decisions: consistency, importance, depth of understanding, and relevancy. As a student said: "Well, we definitely did not include like the information that we did not know much about... So we've looked at things that we've seen consistent… that we all knew." For example, the students working on a super note about DNA engaged in shared reflection to identify the "big ideas" related to DNA. As a member commented, "We tried to determine the biggest thing in DNA, and how that worked." They composed their super note focusing on the essence of DNA: "Now we understand that DNA is the building blocks of life. It acts as a code for the cells. This code instructs the cells to produce different body proteins."

To formulate coherent understandings of the complex mechanisms underlying many of the topics (e.g., DNA, immune system, heart holes), students in each group needed to work collaboratively and combine the specialized knowledge and information they had gained to understand the full picture. As a student from Mr. M's class reflected in the interview: "I actually worked with a friend on this [topic about heart holes], and she was mostly working on where heart holes are, like I told you they are on the septum, and I was working on how they heal. And she asked a question on the regular view on "how do the heart holes heal?" so I've researched that and we kind of combined our ideas, and put [them] in a super note." The super note created by these two students is shown in Figure 3.

<Insert Figure 3 about here>

The teachers also asked students to show their final drafts of super notes before posting them to the Super View. Doing so encouraged students to write careful super notes and get their teacher's advisory input. To guide super note writing, both classrooms analyzed the super notes from previous classrooms to illustrate the use of the scaffolds. Students noticed the writing style to present the information in a simple and clear way in order to make it accessible to students from other classrooms. Students noted the importance of accessibility in the interview: "We used simpler words so people would actually understand." When a super note is structured well, it helps in understanding the research journey that other teams have went through, from the early questions and thoughts to deeper understandings.

How did the students interact with the super notes to support knowledge building?

As noted above, students had access to the knowledge progress of their partner classroom as well as the prior classrooms (student cohorts) through reading their super notes. We extracted data from the Knowledge Forum and conducted social network analysis to trace who had read whose super notes. As Figure 4 shows, the students from the two current classrooms formed extensive connections through reading one another's super notes. Only one student (from Mr. M's room) shows as an isolated note due to her absence during the late part of the science unit. The social ties included within-community reading of the super notes created in their own class, between-community reading of super notes from the other classroom and those synthesizing the ideas of the previous classrooms. On average, students read the current year's super notes more actively (34.60 readers per note) than those from the prior classrooms (19.83 readers per note). Focusing on the social ties formed between the two classrooms of this study, we further calculated the homophily measure E-I index (Krackhardt & Stern, 1988) to gauge the relative density of internal connections within a community compared to the external ties with the members of the other classroom (E-I index = -0.09). E-I index has a value that ranges from -1 (all ties are internal) to 1 (all ties are external). The above result of E-I index close to 0 suggests a balance between within- and cross-classroom reading interactions.

<Insert Figure 4 about here>

Each classroom had a whole class discussion about the information gained from the super notes, followed by further small group discussions focusing on the super notes most relevant to their own inquiry. Through qualitative analysis of the video records of the whole classroom discussions and student interviews about how they approached the super notes, we identified specific patterns characterizing how students worked with the super notes to enrich their knowledge building efforts. The patterns clustered around three themes, as elaborated below.

(a) *Encountering and enriching: Encountering a broadened scope of ideas and interests for mutual learning*. The super notes enabled cross-classroom exchanges so students could encounter a broader scope of ideas and interests for mutual learning and knowledge building. This included finding ideas to help deepen their own inquiry and accessing questions and knowledge in specialized topics that they did not inquire as much in their own work. For example, while both classrooms investigated how the immune system works (see Figure 2), Mr. B's students conducted specialized inquiry in allergies and created a super note in this area, which was not covered by the students of Mr. M. During the classroom discussion, 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 had learned something interesting from the super note about allergies written by Mr. B's students. Another student pointed out a deep concept learned from a super note of Mr. B's class related to their own work: "Me and J are doing the 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… it was really helpful for us…"

In the final interview, students from both classrooms noted how the super notes helped them learn from one another across classrooms. As a student said, *"I actually really like how students, my fellow classmates take a different turn on their understanding from what the teacher says. So I really like the super notes because the students are actually being the teachers but to each other."* Another student commented on mutual sharing of diverse specialized knowledge: *"I learned a ton just from my studies, and from 23 other people in my* *class I learned a ton more… and even combining our brains with the other class... like… how much knowledge would be there?"*

(b) *Reflecting and deepening: Reflecting at the crossroads of ideas for deeper thinking and inquiry*. While the different classrooms shared a set of common inquiry topics focusing on the primary human body systems (see Figure 2), students' super notes summarized somewhat unique ideas and questions that were most interesting to their inquiry. Reading the different ideas in comparison to their own inquiry work created opportunities for students to reflect on the different perspectives and identify connections and gaps for deeper thinking, individually and collaboratively. As a whole class, students discussed the different ideas from their partner and their own classroom and reflected on the connections with the teacher's facilitation. For example, Mr. B asked: "*What was the idea that came from the super notes that you hadn't thought before and that pushed your thinking further?*" A student shared her reflection on a super note she read about the brain: "*Well I never really thought about what side of the brain controls what side of the body… but it turns out that your left side of the brain controls the right side of your body*."

Key ideas and questions identified from the super notes became the focus of deeper inquiry and dialogues to develop connections and address deeper problems. For example, students in Mr. B's room discussed the super note about heart holes written by Mr. M's students (see Figure 3), which highlighted why heart holes can be dangerous. In Mr. B's classroom, students identified this topic as interesting and discussed the specific impact of heart holes, revealing deeper understandings of how the heart and lungs work.

[16] K: Um, like the heart hole. I heard of them, but I didn't know how that really works.

[17] S: if you can have a hole in your heart, without it, like, immediately, you exploded.

[18] Teacher: Well… what's the problem if you have a hole in your heart? …They said kind of clearly…something really interesting about what the heart does… D?

[19] D: It's like really dangerous if the blood mixes.

[20] Teacher: Right, the blood mixes, but why is it bad if the blood mixes?...

[21] B: Because if they mix together, if they mix, …they will be as bad as like breathing carbon dioxide.

[22] Teacher: A, do you want to build on?

[23] A: Because the blue side like that has no oxygen.

[24] Teacher: This side, no oxygen (writes "no oxygen" on the blue part of the figure on the Smart Board).

[25] A: And other part has oxygen.

[26] Teacher: 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.

[27] S: (reads the super note) 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...

[28] Teacher: 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?

[29] 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.

[30] Teacher: Yeah. Do you want to build on that, M?

[31] 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.

[32] Teacher: So it's working with oxygenated blood, and blood with no oxygen. C?

[33] 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, 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 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 develop elaborated explanations of the processes. The above discussion further led to an improvised participatory activity in the classroom in which the class members simulated how the blood travels to collect and transmit oxygen. The teacher played the heart, and three students played the red blood cell, lungs, and the rest of the body, respectively. The whole class was involved in discussing where the blood cell should go next, and what changes occurred as the blood cell traveled from one place to another.

In the final interview, students commented on how the super notes supported their reflection, wondering, and inquiry. Student G from Mr. M's class commented on seeing the different perspectives: "*I like how we are to see the notes from the other classes because…even though they are not learning about the same thing… and maybe one of them is focusing on the same thing, but it is still different. So it is really good to get a new mindset* *of the topic."* Several other students commented on how the super notes further inspired deeper thinking and inquiry: *"I did not know that you could get holes in your heart, and then I'm kinda wondering about them to know a little more." "All of these notes are sort of just like the basics, but once I got interested in that topic from the note, I sort of went into a deeper research about it, so I could find out more."*

(c) *Rising above: Putting together knowledge from the different areas and communities to develop a complex system view*. Through working with the well-formulated "big ideas" and questions about the different inquiry topics, students gained opportunities to take a deep view in each human body system and, at the same time, rise above the different topics to understand the connections between the different systems, which are essential to the complex functions of the human body. The following shows an excerpt from Mr. B's classroom in which students reflected on the "big ideas" they learned from the different super notes, integrating the core concepts about the different body systems to formulate high-level understandings.

[35] Teacher: … Is there anything that you could say about the body as a whole, like a really big idea, about how the body works …that you understand differently now?...

[36] C: when you got hurt, it would trigger the nerves, but then the nerves would just lead through your whole body to the brain, and what I understand is that there is the spinal cord.

[37] Teacher: There is a whole spinal cord system. That is really important to relate...

[38] L: Everything is sort of, part of like a system…Everything is like I can say work together. Like the circulatory system isn't … just the heart. There [are] a lot of details to it. Like even in vein…it [has] different types of cells, so many things.

[39] Teacher: Everything is part of a system, and everything works together. [L: That's what I said]

[40] K: So like, I used to think, like 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 so, now I understand that like each part of the body has…its own little system…Like the heart has its whole procedure, the lungs have a procedure, and all different things, all at the same time.

This excerpt of classroom discourse showcases several vertical moves to dig deep and rise above. In Line 36, student C digs in the processes underlying the sensory perception of pain involving nerves, the spinal cord and brain. Following the teacher's rephasing of the spinal cord as a system, student L in Line 38 makes a rise-above move to view everything in the human body as a system working together. This point is repeated and revoiced by the teacher in Line 39 for emphasis and clarity. In Line 40, student L further elaborates on what it means to be a system, highlighting personal conceptual change from a simple, centralized system view of the body ("the brain told the body what to do and that was the end of it") to a new understanding more aligned with distributed dynamic systems (each part has "its own little system" and processes, all taking place "at the same time").

Following the above episode of classroom discourse, students continued to discuss the most important connections across the different body systems. They identified connections formed through the heart, brain and nerves, as well as cells and DNA at the fundamental level. As the students said: *"DNA is a base code of everything. It's the foundation for organisms." "When you are first born [formed], you are a cell, and it is literally what makes up your whole body…And then like, in the end like five hundred thousand, 'cause it just keeps on duplicating, because of DNA."* As conceptual rise-above, student explanations of cross-system connections evolved from the more visible connections through blood and nerves to the underlying life processes (e.g. cell division and DNA) shared by the body systems.

Discussion

This research investigated how teachers and students approached super notes as boundary objects for cross-classroom knowledge building, which was designed using an emergent, multi-layer interaction approach. Based on the findings, we discuss the following three components of this approach to inform future design and research.

The Creation and Sharing of Super Notes as "Epistemic Boundary Objects"

The findings revealed students' notions of super notes (see Table 1), which recognized the dual-purpose nature of super notes for both epistemic advancement and social boundary crossing. On one hand, super notes served to enhance students' reflective advancement and rise-above of ideas: to review the diverse idea contributions of their community and formulate "big ideas" achieved through various lines of inquiry supported by the super note scaffolds. On the other hand, super notes provided a means for students to share their knowledge advances with broader knowledge builders in an accountable and accessible manner. Consistent with their students' views, the teachers emphasized that super notes needed to show a higher level of reflection and refinement than regular notes and capture "juicy" areas of inquiry that might be interesting to their partner classroom. The teachers and their students found the super note scaffolds helpful in offering a consistent and common structure for synthesizing their knowledge advances in a way that students from the other classroom could understand. The common features of super notes make them possible to serve as boundary objects (Star & Griesemer, 1989) to support cross-community interaction.

As the above findings suggest, super notes represent a unique type of knowledge artifacts in collaborative knowledge practices. We propose the concept of "epistemic boundary objects" to capture their role in supporting both epistemic rise-above (Scardamalia, 2002) and social uprising of ideas in cross-community knowledge building. Epistemic boundary objects refer to knowledge artifacts that offer (reify) rise-above syntheses of inquiry with a boundary-crossing structure, serving to synthesize and consolidate emergent knowledge advances in a community and further support cross-community sharing and interaction. Creating such artifacts requires students' high-level epistemic engagement: to reflect on what they know, at what levels of complexity and certainty, and what they need to better understand and investigate. At the same time, such artifacts offer a means of translation (Star & Griesemer, 1989) for bridging the different social communities and spaces. Creating epistemic boundary objects, such as in the form of super notes, provides a joint intentional focus and authentic context for students to continually advance and improve their ideas for broader impacts.

Supporting Epistemic Advancement and Social Uprising of Ideas as Interconnected Processes

The results further provide a detailed account of how students created super notes as their knowledge building work proceeded. The processes encouraged students to improve their ideas toward higher epistemic levels in order to share advances with other classrooms. Navigating the Super View as a cross-classroom space and reading the prepopulated super notes served to give students a larger creative context with a sense of the high-level questions and knowledge progress that they should aim for. They then engaged in collaborative and reflective processes to generate super notes based on their knowledge building work, including discerning and framing emergent directions of inquiry as a whole community, reviewing progress and gaps of inquiry in each area in groups and deepening and refining their knowledge accordingly, and formulating coherent insights and "big ideas" in light of the diverse idea contributions. As a result, their super notes showed a high epistemic quality (Table 2) in capturing sophisticated scientific understandings (explanations), with deeper issues and questions further identified.

The analysis highlights the dynamic link between epistemic advancement and social uprising of ideas. Students' cognitive and metacognitive efforts to transform their ideas and inquiry toward higher epistemic levels are motivated by and further contribute to their goal to produce knowledge advances of value to the larger collective for cross-community sharing. As the teachers reflected in the interview, sharing with boarder knowledge builders gave students an authentic purpose: to produce new and improved understandings of value to peers from their own and other communities, who may learn from and build on their ideas. Thus, students needed to work intentionally to dig deep into the underlying issues and mechanisms of the human body systems and rise above the specific information and ideas to formulate coherent explanations and "big ideas," which might be useful and interesting to the broader audience.

Interacting and Dialoguing with Ideas across Spaces, over Time

In this research, the cross-community interaction started with the mutual sharing of super notes in the online meta-space to build shared awareness of the inquiries and knowledge advances in different classrooms; it further continued and unfolded within each classroom as students brought some of the ideas to their own classroom's discourse to deepen their own inquiry and build connections in-between. In the meta-space, students developed extensive social ties with other peers through reading the super notes (Figure 4), supporting idea contact across the various areas (and emergent groups) of inquiry between the different classrooms. Students further brought the insights they had gained from the meta-space to their own classroom for continual inquiry. The analysis of the classroom discourse revealed various productive ways to interact with the ideas from other communities to further their knowledge building. These included (a) encountering a broadened scope of ideas and interests for mutual enrichment, (b) reflecting at the crossroads of different ideas for deeper inquiry, and (c) rising above knowledge from the different areas and communities to formulate a higher-plane view. While each super note offered a rise-above synthesis of a line of inquiry about a specific human body function in a classroom, the extended discourse taking off from the super note sharing allowed students to further connect the different lines of inquiry to explain how the human body systems work together.

Conclusions and Implications

This research generated conceptual and empirical insights in how to extend CSCL interaction to higher social levels across different classrooms in a way that supports epistemic advancement of ideas using a multi-layer emergent interaction approach. Based on the framework and findings, we propose the following principles to guide future design and research. (a) *Climbing the social and epistemic ladders together*: Cross-community knowledge building should leverage social uprising and epistemic advancement of ideas as interconnected processes. The process to transcend student ideas toward the higher social levels for broader sharing further provides an authentic context and demand for students to improve their ideas toward higher epistemic levels. (b) *Creating epistemic boundary objects*: Students' co-creation of and interaction with super notes, as epistemic boundary objects, provides an anchoring activity pattern that can boost epistemic and social emergence of ideas. And (c) *sustaining idea interaction across levels and spaces*: Knowledge building interaction can be sustained through flexible integration of local (within-community) knowledge spaces and a meta-space shared across communities, with dynamic idea movement across the social levels and spaces. Valuable ideas developed in each community have the opportunity to travel up to the cross-community space for extended sharing and higher-level discourse; At the same time, insights gained from the cross-community space are brought back to each community to stimulate further inquiry and discourse and develop integrated understandings in light of the knowledge and perspectives from the different communities.

Building on the insights gained through the reported study, we have been continuing this design-based research to further elaborate the classroom processes and create technology support. A multi-level collaboration platform has been designed to support knowledge building across classrooms: Idea Thread Mapper (ITM, http://idea-thread.net). ITM's discourse tools interoperate with Knowledge Forum; it further incorporates (a) metacognitive and epistemic support for students to co-organize the collective journey of knowledge building in each classroom and reflect on shared progress over time, and (b) boundary crossing support for cross-classroom sharing in a meta-space, including tools to launch cross-classroom collaboration dialogues focusing on challenging problems of common interests. In the follow-up iterations of this research, we will conduct deeper analysis to investigate how student ideas improve toward higher epistemic levels as student work and interact across the different layers of knowledge spaces and how cross-community discourse operates to address larger challenges rising above the ideas of from each community. Supported by ITM, future studies will test cross-community knowledge building in an international network of classrooms, which work across social and cultural boundaries to investigate critical problems facing the global and local communities.

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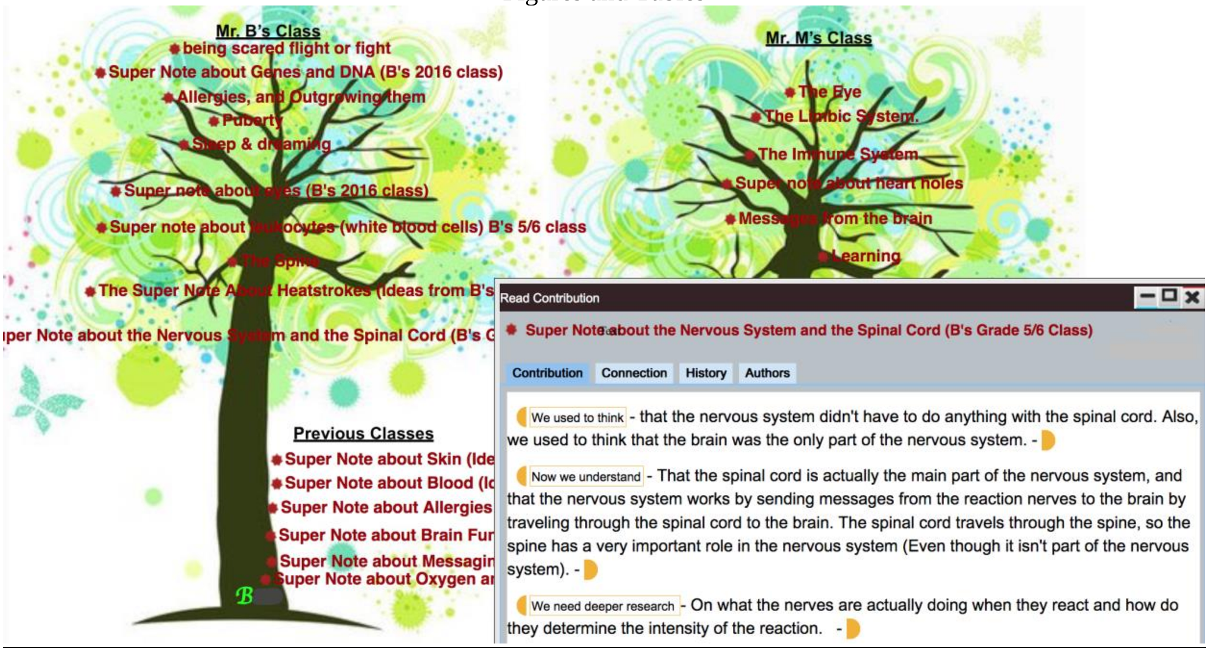

Figure 1. The “Super View” for sharing super notes between classrooms with an opened super note.

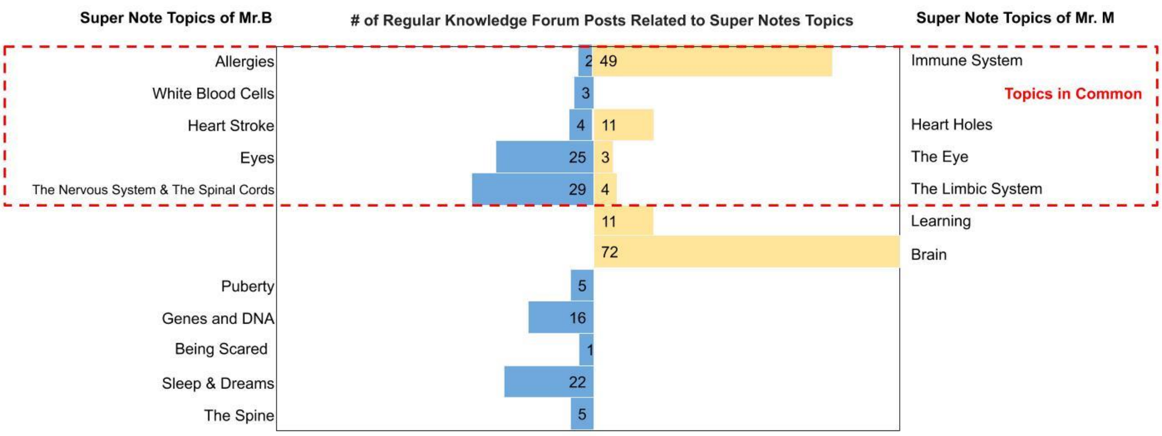

Figure 2. Super notes created by the two classrooms in relation to their regular notes.

Super note about heart holes

Our topic and problems Why do hearts get holes in it? And how does it heal?

We used to think that it would heal by itself overtime. We also thought that the hole(s) was on the outside of the heart

Now we understand 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. It can be dangerous when the blood mixes because it's like breathing carbon dioxide instead of oxygen.

Now we understand that some people who are born with heart holes in their septum will heal overtime. Whereas some people will have to get an open heart surgery to close the holes where a machine takes over the heart's pumping action and moves blood away from the heart.

Figure 3. A super note about heart holes from Mr. M's Class.

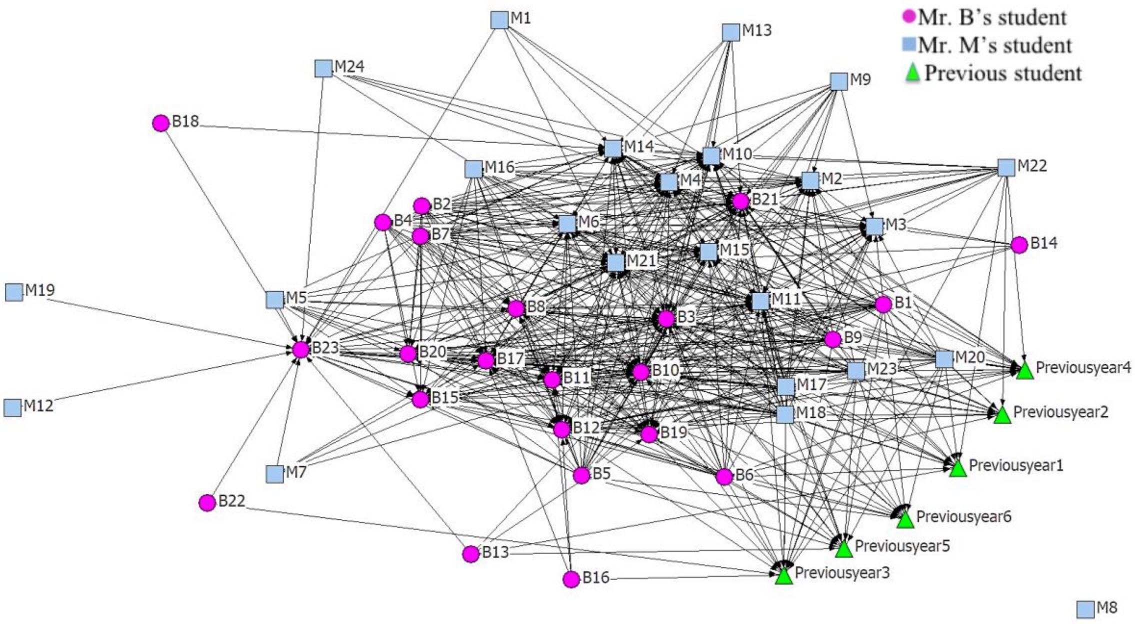

Figure 4. Social network analysis of who had read whose super notes created by students of Mr. B, Mr. M, and the previous classrooms. Each node represents a class member, and each line shows a social tie.

Table 1: Students' conceptions of the super notes captured in the interviews.

Themes of conceptions	Class	Examples from the student interviews
1) super notes as a summary of "big idea" and knowledge basis	Both classes	"I think it is to focus on the entire idea of the topic you are focusing on and not just the tiny details you wanna share with the whole class." [….] "So it's just I think the basic basic idea."
2) super notes for capturing and sharing the journeys of inquiry	Both classes	" It's like one huge note that reflects on all of your ideas, and what you used to think and what you now know. So I thought it was a great idea rather than making a bunch of notes on your progress of learning a topic."
3) super notes as knowledge for others	Both Classes	"…it's kind of to let everybody know what you are researching, but without having to read like all the stuff that you've read and having the basic knowledge of that topic." "I really like the super notes because the students are actually being the teachers but to each other."
4) super notes as refined and accountable knowledge	Both classes	"Well, we definitely did not include like the information that we did not know much about, because that would mean that… like if you were not sure if that was right or not, then it would not be good to include it. "
5) super notes as well-phrased and accessible ideas	Mr. B's class	"When you look at normal notes… there maybe some spelling errors, and maybe some like grammar errors… If you look at super notes that are amazingly written and they are really simple and they help people understand what is the main focus of this super note."

Table 2: Coding of student ideas synthesized in the super notes based on scientific quality and epistemic complexity.

	Ideas summarized under "We used to think…"	Ideas summarized under "Now we understand…"
Scientific quality 1. Pre-scientific	7	
2. Hybrid	6	
3. Basic Scientific	2	1
4. Scientific		15
Epistemic complexity 1. Unelaborated Facts	14	
2. Elaborated Facts	1	4
3. Unelaborated Explanation		1
4. Elaborated Explanation		11

Note: Among the 16 super notes written by the students, one super note used the scaffold "Now we understand…" without "We used to think…"