Idea Development Across Social Levels for Knowledge Building in Four Grade 5 Science Communities

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Abstract: This research contributes to addressing a core gap of knowledge in CSCL to understand idea emergence and interaction across multiple social levels including individual, small group, community and community networks in order to inform designs to foster extending inquiry trajectories. Using design-based research methodology, this study investigated how students in four grade 5 knowledge building communities worked across the boundaries of the social levels to develop deep understandings of human body systems with the support of Idea Thread Mapper and Knowledge Forum. As students conducted focused inquiry and discourse in their own community, they formulated a challenging question for the four classrooms to collaborate on: how people grow. Qualitative and quantitative methods were used to investigate how new ideas emerged in individual classrooms and rose above to the cross-community discourse to understand this challenging issue, with new insights further diffused to different classrooms for further inquiry and connected discourse.

Introduction

Educational researchers have made substantial advances to develop computer-supported collaborative learning environments and support collaborative knowledge building among students (Engle & Conant, 2002; Scardamalia & Bereiter, 2006; Slotta, Suthers, & Roschelle, 2014). Further research is needed to extend interaction to higher social levels and scales (Stahl, 2013), so students can build on the knowledge of other communities across school years for sustained knowledge building. This requires designs for cross-boundary interaction and collaboration, which has gained interest in the broader fields (Star & Griesemer, 1989) but still lacks systematic investigation in the field of computer-supported collaborative learning. This design-based research tests and refines designs of cross-classroom interaction for knowledge building with the support of a new collaborative learning platform: Idea Thread Mapper (ITM) (Zhang & Chen, 2019). Based on previous research (Zhang, Bogouslavsky & Yuan, 2017, Yuan & Zhang, 2018), this research designs cross-community interaction using a multi-level emergent interaction approach, focusing on idea emergence and movement across multiple social layers. In the multi-level emergent interaction framework, at the micro-level students co-generate the interactional frame of Knowledge Building (KB) norms, metacognitive meeting rules, and distribute workloads and collaborative responsibilities in the community. As students conduct their inquiry studies over the school year, they further create reflective knowledge synthetics (Yuan & Zhang, 2019) to share their knowledge with peers. The stable material content structures which has with four scaffolds in writing (Our research question…; we used to think…; Now we understand…; We need further research…) emerged and directed their future learning. The collective knowledge of the classrooms taps into the knowledge accumulated at the individual class level as the individual class is the basis of organizational knowledge creation (Figure 1). At the macro level, the design of the "Super Talk" fulfills the needs of cross-community interaction. The Super Talk as a collaborative online space enables students from four classes work together to address the same challenging research problem. The learning results further impact downward and transform the learning dynamic back to each class and individual student as students who participated in the Super Talk read and write notes and bring what they have learned back to the home class. Idea Thread Mapper provides a technology infrastructure with a trustworthy and vetted background database created by students about their learning subjects.

This paper attempts to deepen the understanding of the cross-classroom interaction in a set of four grade 5 knowledge building classrooms supported by ITM. Our research question asks how students interact across multiple social levels to build knowledge in knowledge building learning communities.

Classroom design and context

This study was conducted in four grade 5 classrooms (with a total of 89 students who were 10-to-11 years old) that studied human body systems over six months using ITM from January 2018- June 2018. The four classrooms, labeled as Class 1-4, were taught by two teachers each teaching two classes. Students in each classroom generated interest-driven questions in human body systems, co-organized research areas focusing on various topics, and conducted research using various resources. They conducted reflective knowledge-building

conversation (called "metacognitive meetings") in their classroom to build on one another's ideas and questions while reviewing their progress. At the same time, for students to continue their conversation in the online space, the teacher organized the same online discussion space in ITM which is called the *Wondering Area* that matches their face-to-face research topics. As progress was made in each idea thread, students co-created and edited a Journey of Thinking (JoT) to reflect on their synthetic knowledge (for details, please refer Yuan & Zhang, 2018).

In the fifth month of this study, as students accumulated enough knowledge and made efforts to advance their knowledge, students in Class 2 proposed a challenging problem for Super Talk across the classrooms: How do people grow? Students in four classes contributed their ideas collaboratively to advance their understanding. Their ideas were further used by another class to advance their understanding.

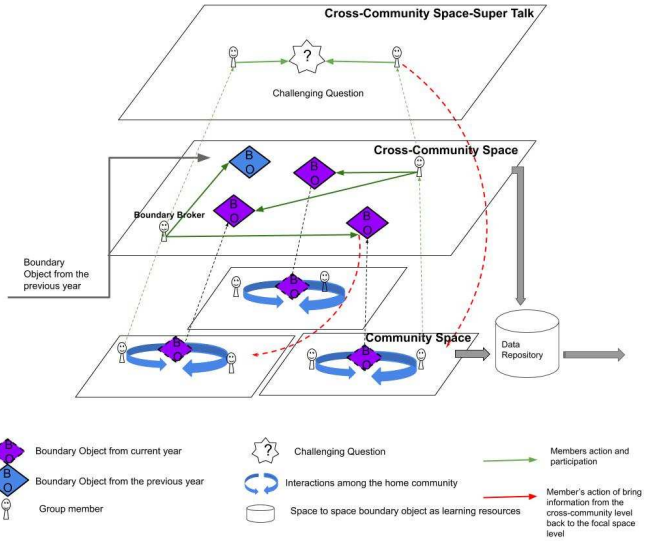

Figure 1. The visualization of the multi-level emergence design of KB Interactions across classrooms conceptual framework.

Data sources and analyses

The data sources include classroom observation notes, video records, transcriptions of classroom conversations, and students' online discourses in ITM. Guided by the research question, we conducted a detailed qualitative analysis of students' inquiry process in their home classes in connection with students' interaction across groups and cross-classroom interactions. We conducted content analysis (Chi,1997) based on the complexity of ideas (from unelaborated facts to elaborated explanations; see coding scheme in Zhang et al., 2007).

To further investigate the quality of the notes posted in the Super Talk, researchers compared students' notes in the Super Talk (cross-community level) and notes in their home class Wondering Areas (group-level). To increase analytic efficiency in this longitudinal data analysis, this study used LightSIDE (Mayfield & Rosé, 2013) to train and build analytic models. First, one researcher coded 550 notes from the previous school year's Ecology unit (September 2017 – December 2017). A second coder coded 12% of the data independently for inter-rater reliability (Cohen's Kappa = .87). The manually coded data were used as the training data to create Natural Language processing models for automated analysis using LightSIDE. Then the researcher used the model to predict the idea complexity of the new data set that contains 633 regular ITM notes from their home Wondering Areas (January 2018 – June 2018).

To understand how students' ideas emerged from home class and contributed to the Super Talk (Figure 3), we read/re-read our detailed field notes and examined the classroom videos to understand the classroom processes, and combined with the detailed video analysis to further understanding the Super Talk generation process.

Results

From Individual to Group: How do individual ideas and interests shape the emergence of groups?

At the beginning of the learning unit, all students in four classes joined the human body kick-off activities. For instance, one activity was to let students participate in doing a high-kick for one minute and measure the

heartbeats and breath before and after the exercise. Based on their reflections and observations, they created their own discoveries and proposed their initial research questions. Based on the nature of their questions, they formed into groups based on similar interests naturally. In general, the brain, heart, lungs, digestion are big groups across four classes. At the early stage, students' questions also closely related to the kick-off activities' and their pre-knowledge (Table 1). Moreover, by posting their questions, students have a sense of group engagement since they get familiar with peers who share the same interests.

Table1: Examples of Students' Individual Initial Research Question from Class 3

Wondering area	**Heart**	**Blood**	**Breathing**	**Digestion**	**Brain**
Research questions	CL23: Does how fast the blood travels through my veins effect my heart rate? How fast does the air in my body take to go through my whole body? CL13: Why does our hearts beat faster after we exercise? CL4: How does the heart go faster when exercising why and how? CL15: Why does your heart beat faster when you work out? Why do you need more blood vessels when you work out? **CL9: Why was my heart beating louder after exercise?** CL3: Why does your heart rate gone when you exercise? CL18: How do you feel your heart beat near your throat or on your arm near the wrist?	CL23: Does how fast the blood travels through my veins effect my heartrate? How fast does the air in my body take to go through my whole body? CL13: Why does our hearts beat faster after we exercise? CL16: How does the immune system work? How does the human body use blood? CL17: How does our body use blood? CL21: Where does the blood go when your exercising and eating?	CL14: How does the human body use air? CL5: Where does the air go in the body when inhaled or exhaled? How does it help you? How does the body help the air travel in it? CL19: Why does your heart rate so faster when you exercise? CL10: How does asthma effect our body? CL20: How does human body use air? CL12: How does air we breathe get around our body? How do we use it? CL22: How does the air in your breath get around the body? Where does it go in the body? How does the body use the air?	CL1: Why does the heart rate and respiratory rate go up when we exercise, where does the food go after the digestion system? CL7: What parts of the human body are used in the digestive system?	**CL2: How does your brain command your body? Common vs reflex?** CL8: How do eyes get their color? The brain controls your systems, but how?

After the kick-off activity, students from 4 classes generated 108 initial research questions, among them, 84% are open-ended questions start with how and why. 16% of the questions are fact-driven questions that start with where, what, and when.

Group-Community: How did ideas emerge and interact across areas in the community?

To further elaborate this learning process, we traced two ideas, *pituitary* gland and *mitosis*, from the Class 3 as examples as these two ideas were shared and exchanged in both group-level and the cross-classroom level discussions.

After the kick-off activity, student Eva (CL2) joined the brain group and posted her first note in ITM about the brain. She first mentioned that the brain has different parts and the pituitary gland by explaining "This is the pituitary… released a hormone that made you grow. This pea-sized gland plays a HUGE role in puberty". At the same time, other group members were using books and online learning materials investigate this brain topic. After the brain group accumulated much knowledge, at the end of the first month, they suggested to have a metacognitive meeting about the brain and shared their learning results with the whole class (Figure 2). Before the metacognitive meeting, the teacher suggested everyone go on ITM and read the notes in the brain idea thread to have a background understanding of the sharing content. To better support students notetaking and reduce the distraction from obscure scientific words and misspellings for Grade 5 students, the teacher pre-wrote the academic words on a white chart (Figure 2). This strategy facilitates students to better focus on their

sharing. The pre and post comparison of students notes suggests that students wrote down more scientific words correctly with more content during the metacognitive meeting in compare with the metacognitive meetings that didn't have pre-written scientific words. During the metacognitive meeting with the main leading theme of brain, Eva stressed the function of the pituitary gland to her classmates, and they discussed how the brain controls the body. After the metacognitive meeting, the brain group designed an online assessment to understand how well their peers understand the knowledge in the brain (Figure 2), the results show that most of their peers had a high level of understanding as they achieved high scores in most of the questions, and the brain group made an instinct explanation on questions that received low scores to clarify the misunderstandings on the spot.

As the learning from each group progressed, in week 5's metacognitive meeting, which has the central theme of how the lungs work, students found that the brain and lungs work closely together, and the oxygen gets to the tissues through red blood cells. Thus, students start to build their basic understanding of the human body at the cellular level. Further, in week 6, the main theme of the metacognitive meeting was the circulatory system. During the meeting, students found that blood circulates through the body and why tissues in the body need oxygen. Student Kevin (ID: CL9) contributed his knowledge about cells as "The cells contain sugar except they need the oxygen to turn it into energy." Halen further builds on saying "oxygen is carried by hemoglobin; it is a molecule that plays a vital role in the metabolism cycle." This suggests that students made closer connections between organs and started to share knowledge at the cell level. In week 7, during the metacognitive meeting, Kevin, as an expert from the heart and lungs group, shared his knowledge about white blood cells in the blood. He mentioned that: "Neutrophils look for things that shouldn't be in your body, and macrophages look for and digest dead germs…Amino acids are what make proteins", and during the reflection, the teacher asked what tissue of our body needs oxygen, and students said everywhere, because we need our oxygen to survive. This information is critical because it advanced the study of cells one step further. As the learning processed, students in Class 3 became familiar with the molecules and cells, which created a good foundation for the brain group. In the following week 8, students in the digestive system led the metacognitive meeting; however, a research question remained: how did the small intestine absorb nutrients and minerals? Since digestion was one of the main kick-off activities, so students were all interested in the topic. The teacher played a video about the small intestine for further explanation of the digestive system to the whole class. This video functioned as another critical piece of information since digestion systems first made connections between energy, cells, and blood, since nutrition is absorbed from the small intestines and then travels through the body in the blood stream.

On March 15th, Kevin posted another note in ITM stating "Mitosis is the process of one cell splitting into two new cells as it is a complex process with many steps". In the same week, when the teacher asks whether they need new threads, and if they feel what they are studying cannot fit in any of the current threads. Kevin suggested the teacher to create a new thread called "How do we grow?" This is the thread that was first established in Class 3. However, this new topic did not get much attention from the home class since there were only two students working on this topic. This advanced idea did not catch others' attention at the end of the 5th month until Class 2 initiated the cross-classroom collaboration with the same question of "How do we grow?". Kevin finally found peers interested in the same topic, so he joined the collaboration and uploaded his note about mitosis to the cross-classroom thread in ITM. Eva did the same, posting her first notes about pituitary glands. At the end of the semester in the 6th month, the teacher held a metacognitive meeting asking about connections to the study of the human body in Class 3. She asked the whole class, "What are some deep questions that they are trying to figure out?" Kevin shared that mitosis connects to cells because it also relates to genes and DNA as it is the basic unit of the body. To grow, the cell has to divide through mitosis. Thus, the concept of mitosis was both explained in the home class and the cross-community area.

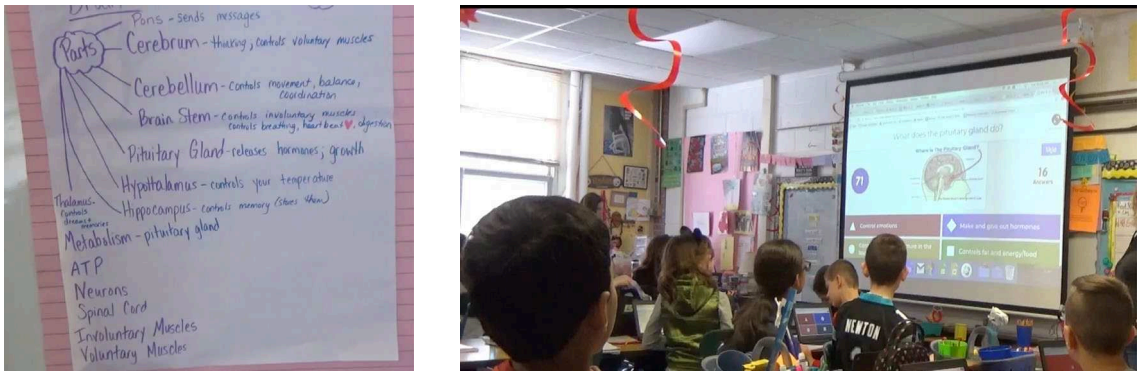

Figure 2. Metacognitive meetings about the concept of the Pituitary Gland.

Cross-community interaction: How did ideas move across classrooms and influence the work in each classroom?

The Super Talk was generated at the beginning of May and lasted to the end of May with a total of 22 students from the four classrooms participating in the discussion. At the beginning of May, at a metacognitive meeting, students in Class 2 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 2 started to discuss possible challenging questions for Super Talk. Three questions were proposed in total: How are all the systems connected? Which two systems are most connected? and Why do people grow? A few students reflected on what they knew about how muscles grow, and several other students showed interest 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 a vote for the one that they felt was challenging and which they were most excited about. The topic of "How do people grow?" was selected. This Super Talk topic was proposed and added in ITM and visible to other classrooms. In the following week, students from Class 2 first started to contribute knowledge about how the brain, bones and muscles grow, drawing 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 2 and discussed what counts as a good note for the Super Talk to guide students' participation and reflection. In the following week, students from the other classrooms started to build on the ideas in the Super Talk (Figure 3). Students collaboratively explained how people grow involving main topics from bone and muscles, brain and nervous systems, cells and genetics, and digestive systems. Approximately 50% of the notes are build-on, reflecting a higher level of collaborative responses.

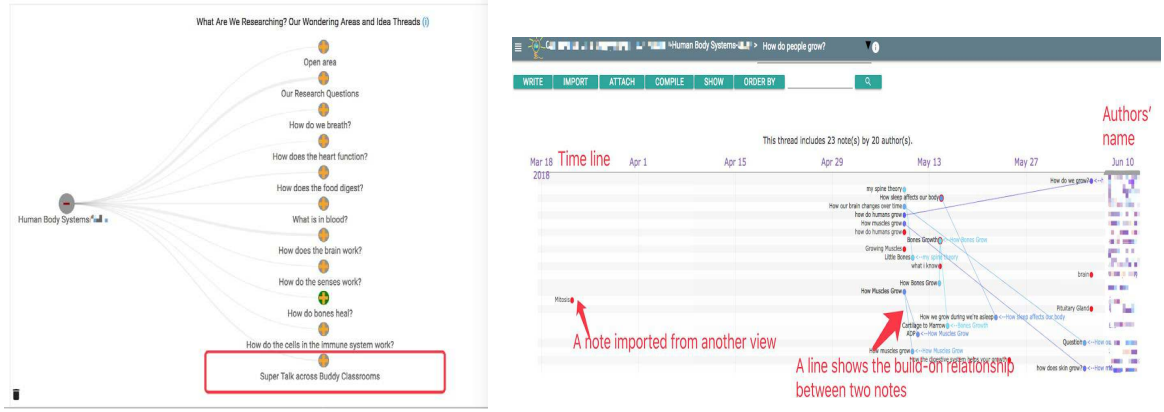

Figure 3. Students' collective wondering areas about human body systems (Left) and the Super Talk area (Right).

To further investigate the quality of the Super Talk, researchers used the LightSIDE software to train and build a Natural Language Processing model. The researchers compared 633 regular ITM notes in the human body unit and 23 notes in the Super Talk page. One experienced researcher examined the labels and manually revised the results as needed. Nine levels of labels were used (Table 2). The coding scheme was based on Zhang and coworkers' (2007) coding scheme; researchers further expanded the coding schemes based on research needs.

Table 2: Coding categories and definition

Label	Category	Definition
L-F	Unelaborated Fact (Refer to Zhang et al., 2007)	Posting a simple fact about a concept
L-EF	Elaborated Fact (Refer to Zhang et al., 2007)	Posting a fact with detailed information
L-E	Unelaborated Explanation (Refer to Zhang et al., 2007)	Posting a simple explanation about a concept
L-EE	Elaborated Explanation (Refer to Zhang et al., 2007)	Posting a concept with detailed and systematic explanations or mechanisms
L-Question Level 1	Question Level 1	Posting a brief question without providing the

		context, specifying gaps of information, or suggesting possible ideas.
L-Question Level 2	Question Level 2	Posting a well-developed question(s) with context/directions of thinking
L-Resource 1	Resource Level 1	Posting a link lacks context, information, explanation
L-Resource 1	Resource Level 2	Posting links of resources with Explanation and Information
L-I	Insufficient Information	Less than 3 words, not a sentence

The results suggest that the notes posted in the Super Talk have more Elaborated Explanations than the average ITM notes. This suggests the high quality of the content in the cross-classroom collaboration area (Figure 4).

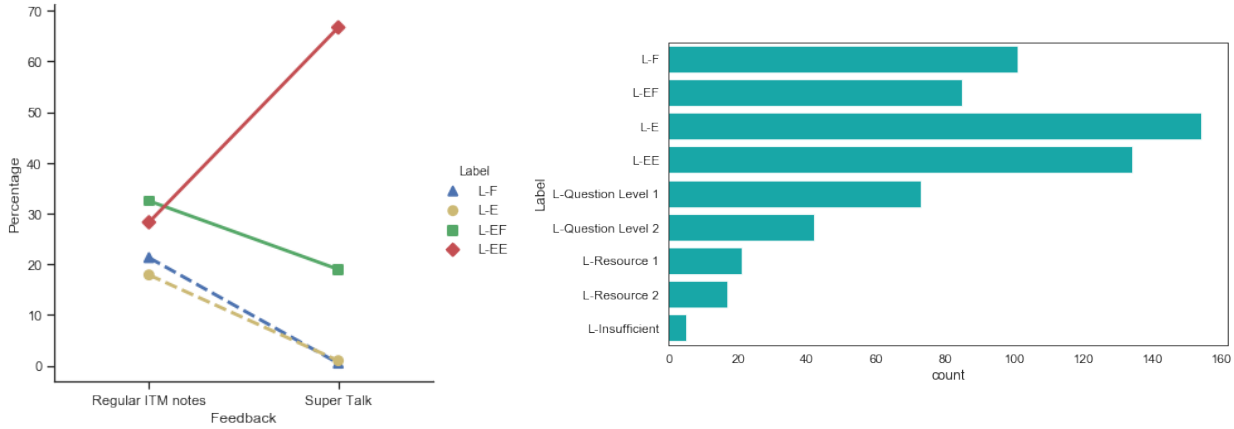

Figure 4. Compare of Idea Complexity between notes posted in the Super Note and Regular ITM threads (Left) The summary of the total 633 ITM regular notes with contribution types (Right).

Discussion and conclusion

The multi-level emergence design and the use of technology in this study tested how ideas emerge, rise above, and interact among communities. The design of this study attempted to address the research challenge of facilitating students' exploration in a tool that enables crisscrossing multi-level idea landscapes (Scardamalia & Bereiter, 2016). The force originating from the sharing and collaboration echoed to the creativity theories in the emergence paradigm, like open innovation which explains the phenomenon of companies making best use of external ideas and technologies in their own business and further letting unutilized internal ideas go outside to the field to be used by others (Chesbrough & Bogers, 2013). At the micro level, through the face-to-face discussion during the metacognitive meeting, students build on each other's ideas, identify the valuable insights and gaps in research. Although different classes may have similar research progress, without the designed cross-classroom interaction, students' ideas may remain in the concrete classroom walls. The two students' learning trajectory mentioned in the results section suggest that students' valuable ideas can disseminate through group discussions and cross-classroom collaboration to benefit others' learning. The Super Talk not only provides students an opportunity to address their urgent needs in investigating challenging questions at the macro-level, but also offers an opportunity for students like Kevin who didn't get much response and worked alone. However, the Super Talk brought a new chance for him to be able to pursue this research question, collaborate with others, and enable his valuable ideas shared through a broaden platform.

It is necessary to highlight the importance of the teacher's role in creating the classroom culture in embracing ideas from the cross-classroom collaboration, and actively making connections between the new ideas with the home class's understandings.

The results of the research question suggesting that ITM supported individual students' ideas emergence and sharing within and across the communities. The use of ITM shows the potential technology in bridging ideas through multiple scales which could not be fulfilled by face-to-face lecturing. Based on the results reported above, this study further demonstrated how key ideas developed through interaction with individuals with other group members, and further extended through the design of cross-community activities. 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(individual) advanced the idea of diversity in the macro-level (community), the discussion results further produce feedback and provide learning materials at the micro-level.

This study sheds 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 results may have several implications for conceptualizing and designing learning space for sustained Knowledge Building across communities.

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