How Did a Grade 5 Community Formulate Progressive, Collective Goals to Sustain Knowledge Building Over a Whole School Year?

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Abstract: This research explores the metacognitive and discursive processes by which a grade 5 community formulated shared deepening goals to direct its inquiry about the human body across a whole school year. This inquiry was facilitated by Idea Thread Mapper (ITM) that supported the community's metacognitive reflection and conversations. Qualitative analysis of classroom activities elaborated the evolution of collective goals of understanding, which were used by students to monitor the community's progress, and regulate further inquiry. Analyses of pre- and post-tests and online discourse showed productive improvement of idea achieved by individuals and the community as a whole.

Keywords: knowledge building, long-term trajectory, socially shared regulation, collective goals, metadiscourse

Introduction

Building on the premise that in the Knowledge Age schools should operate as knowledge-creating organizations to engage students of all levels directly in sustained creative work with ideas (Scardamalia & Bereiter, 1999), recent research efforts strive for innovations to transform classrooms into knowledge-building (or knowledge-creating) communities (Bereiter & Scardamalia, 2014; Bielaczyc et al., 2013). In a knowledge building community, members build on and advance the collective knowledge assets of their community through sustained inquiry and idea improvement: by engaging in idea-centered dialogues involving multiple perspectives, constructive criticism, and distributed expertise; by formulating deeper problems as solutions are developed; and by assuming responsibility at the highest levels instead of relying the leader to direct their actions (Bereiter, 2002; cf. Dunbar, 1997; Sawyer, 2007). The inquiry-based efforts are self-sustained over a long term as a progressive, collective trajectory (Zhang et al., 2012, 2014). This study explores the processes by which a knowledge building community formulates collective deepening goals to develop a progressive shared trajectory of inquiry to sustain knowledge building.

Building a sustained trajectory of inquiry for productive knowledge building requires students to take on collective cognitive responsibility (Scardamalia, 2002). They need to enact socially shared regulation: to construct shared goals, plan collaborative actions, monitor collective progress and engagement, and adapt collaborative processes to optimize members' contribution to achieving their shared outcomes (Järvelä & Hadwin, 2013; Winne, Hadwin, & Perry, 2013). However, collective and socially shared regulation of collaborative learning as an emerging new frontier of research in collaborative learning has mainly focused on short-term collaboration of small groups to solve pre-defined problems or complete pre-specified tasks. In those contexts, students' collective regulation usually focuses on "regulating how to follow the directions, divide up task components, or complete superficial task components" (Rogat & Linnenbrink-Garcia, 2011, p.394). Sustained knowledge building requires all collective members to take much higher levels of responsibility for progressively defining what they need to understand as their understanding is continually advanced over an extended time period (Scardamalia, 2002). As a critical component of such high-level responsibility and regulation, this research explores the evolution of collective shared deepening goals in a knowledge building initiative within a whole school year. In a dynamic system of knowledge building, collective goals are not pre-defined by the teacher or a student leader, but emerge from ongoing interactive discourse across the social levels of individuals, small groups, and the community. The collective goals of a community are co-constructed on the basis of the emergent goals and interests of individuals or groups and continually reviewed and deepened as progress is made (Zhang et al., 2007, 2009). Therefore, students need to develop reflective awareness of the diverse interests and deepening ideas of their community as reflected in the ongoing discourse, formulate shared deepening goals, plan for joint and complementary contributions, and trace progress (Zhang et al., 2009).

This study supports such collective regulation of long-term knowledge building efforts through metadiscourse: metacognitive conversations about the ongoing conversations focusing on collective goal setting, progress review, and planning (Scardamalia, 2002; Zhang et al., 2009, 2014). In online environments that support knowledge-building discourse and conversations, students' ideas are distributed across individual postings and comments over time (Suthers et al., 2008). It is hard for students to monitor the shared focuses evolving in the discourse and the progress made, especially in long-term online discourse (Zhang, 2009). To make collective focuses and knowledge trajectories in extended knowledge building discourse visible to students for ongoing reflection in support of progressive deepening goals, our team created a timeline-based collective knowledge mapping tool: Idea Thread Mapper (ITM) (Zhang et al., 2012, 2013). ITM support the metadiscourse and reflection of students: to define focal topics of inquiry, select and visualize important discourse entries addressing each topic, as an idea thread; and map out the whole inquiry as clusters of idea threads that address interrelated problems. The knowledge progress in each idea thread is further reviewed by students through co-authoring a "Journey of Thinking" synthesis focusing on focal problems, "big ideas" advanced along the inquiry process, and deeper actions needed for further work. This research examines how a grade 5 science community developed collective shared progressive goals to foster sustained knowledge building supported by ITM and related classroom artifacts.

Methods

Classroom contexts

The study was conducted in a grade 5 classroom (with 22 students in the fall and 21 students in the spring) in upstate New York. The students investigated human body systems over a whole school year, with two science lessons each week. Prior to this study, the teacher, who had 10 years of teaching experience, participated in a three-day workshop to learn about knowledge building principles and activity designs (Scardamalia, 2002; Zhang et al., 2011). Following the knowledge building principles, students engaged in all kinds of knowledge activities to expand their community's knowledge, including individual and small group reading and online searching, whole class meetings to share and reflect on work in progress, student-directed experiments and creation of knowledge artifacts, as well as student-designed presentations about individual and small group knowledge advancement. Initial wonderments, improved ideas, deepened questions, and refined theories from these activities were shared in Knowledge Forum (Scardamalia & Bereiter, 2006) for continual knowledge building discourse. To make collective knowledge progress in online discourse visible to students, we used ITM in the middle (early January) and at the end of the school year (late May and early June). During all these knowledge building activities, the teacher, who positioned himself as a facilitator and co-learner, encouraged students to take on collective responsibility (Zhang et al., 2009) to identify collective knowledge goals, plan collaborative activities, share and reflect on ongoing progress within the community.

Data sources and analyses

To examine the effectiveness of knowledge building, we conducted a pre-test in mid-September and a post-test in early March. The test had nine open-ended questions that required students to explain how different human body systems work together. Due to student changes over this school year and schedule conflict, only 13 students took both the pre-test and post-test. Student answers were rated in terms of scientific sophistication, which examined the extent to which students' ideas align with a scientific framework on a five-point scale: 0 – no answer, 1 – pre-scientific, 2 – hybrid, 3 – basically scientific, and 4 – scientific based on our previous studies (Zhang et al. 2007). Using this coding scheme, two raters independently coded all the answers, resulting in an inter-rate agreement of 99.15% (*Cohen's Kappa* = 0.98).

To trace the evolution of collective goals and related inquiry, we conducted qualitative analysis with rich classroom data. Specifically, we analyzed observation notes that recorded classroom activities across the whole school year. A close examination of those notes helped to identify the most critical moments when collective goals were formed, adapted, and represented using related classroom artifacts (e.g. a collective wondering list). We then selectively zoomed into relevant videos of the classroom moments to understand the process of goal evolution. The videos were transcribed and analyzed using a narrative approach to video analysis (Derry et al., 2010). Complementing the video data of the whole class processes, we also analyzed three students' notebooks using content analysis (Chi, 1997) focusing on the goals of inquiry.

To examine how individuals, small groups, and the whole community carried out inquiry and discourse to address the collective goals, we conducted content analysis of student's online discourse, idea threads and Journey of Thinking recorded in ITM, and their final presentation posters at the end the academic year. Each Knowledge Forum note was coded using the coding scheme presented in Table 1 focusing on the emergent collective goals in this community. Two raters independently code 20% of the notes (667 in total) to assess inter-rater reliability, which was found to be 98.5% in inter-rater agreement (*Cohen's Kappa* = 0.95).

Table 1: Content analysis of students' online discourse based on collective goals of inquiry

Focal goal	Description	Example
1. Why do we have muscular and skeleton system?	Students ask questions or share information, about bones and muscles.	"How many bones, muscles, and joints are there in the human body?"
2. How does the brain function?	Students make notes about the architecture of the brain, roles of the different parts in the brain and related nerves to support thinking and sense.	"The brain sends the messages to your brain stem, the brain stem then sends the messages straight to your spinal cord. Then it sends it to the appropriate nerve. "
3. How does the human body develop?	Students ask questions, or share information about the functions of different body parts.	"We have nose hair so the dust won't go all the way into our nose and some dust do have germs."
4. How does the immune system work?	Students ask questions or share information about allergies, diseases, germs, virus, drugs and health issues.	"Maybe HIV won't kill you it will just shut down your immune system so other virus can do the job."
5. Why do we have a digestion system?	Students make notes about food, nutrients, energy transfer, as well as the organs that function as part of the digestion system.	"Did you know that your teeth is part of your digestive system? Because that helps you chew food and send it down to your stomach. Teeth is your first part of your digestive system."
6. Why does blood circulate through the human body?	Students share information or ask questions about heart, blood vessels, veins, and how nutrients, oxygen, carbon dioxide are transported.	"What does the blood carry through the human body? I know that blood carries oxygen, but does it carry anything else? Does blood carry carbon dioxide too?"
7. How do vocal cords work?	Students make notes about how we talk, the structure of the vocal cords, and how do they help to make sound.	"Vocal cords vibrate to make sounds but what makes the vocal cords vibrate?"
8. How does the respiration system work?	Students make notes about the organs that help to breathe and explain the process that oxygen is delivered into the body and carbon dioxide is taken out.	"Why do we sneeze? What happens inside the body when you sneeze?"
9. Why do we have cells?	Student share information or ask questions about the structure, types and functions of cells.	"Without glia cells our neurons would not work properly. With trillion of support cells it helps a lot with the neurons."

Findings

Content analysis of students' pre-test and post-test

Individual knowledge advancement was assessed based on the pre- and post-test that focused on deep explanations. A paired samples *t*-test revealed a significant difference between the pre-test (M=1.43, SD=0.63) and post-test (M=2.99, SD=0.78), t (13) =-7.61, p<.001. Specifically, students' ideas were mostly "2 – hybrid" at the beginning and mostly "3 – basically scientific" in the post-test.

Qualitative analysis of classroom observation notes, classroom videos, and students' notebooks

This inquiry began with a kick-off activity in late September. Students watched a short movie that triggered deep interests in the amazing functions of the human body. Understanding how the human body works was identified as the overarching topic of this year's inquiry. The whole class began to negotiate collective goals after the kick-off. The negotiation originated from initial questions that students were really curious about. The teacher collected all those questions and read them one by one to students. Students realized that some of them were posing the same or similar issues. Therefore, the teacher suggested the students to work in groups to integrate these individual questions into high-level questions. The groups then shared their big questions. The teacher helped clarify these questions and encouraged students to rephrase them in a more scientific way. By the end of the first week (September 24), they came up with an initial list of four collective questions, as the community's shared goals: Why do we have bones? How does our brain function? How does the human body develop? How does immune system work? Then the teacher used the metaphor of a tree trunk and branches to visualize the collective questions, and encouraged student to add more big branches to the community tree as their inquiry proceeded. One week later, students had a metacognitive meeting to share and reflect on collective knowledge progress. They sat in a circle, read KF notes projected on a screen together, and found that some of the notes "didn't fit existing collective questions." So students suggested that they might need new collective questions. Therefore, they generated the fifth collective question based on notes about food and water—Why do we have a digestion system? (Added on October 1)—and the sixth collective question related to heart and blood: Why does blood circulate through the human body? (Added on October 3). The six knowledge goals were recorded on a chart paper, which was posted on the classroom wall as a collective guide (see Figure 1). Each student then chose one big question as his/her focal area based on interest and added the name on a sticker note next to the question, leading to the formation of temporary/ flexible research groups. The teacher encouraged students to add more "branches" onto the collective question list if none of the questions reflected their focal interest. Two students who had done initial research about vocal cords talked to the teacher. The teacher suggested that they start a new area about vocal cords, with two additional students who shared the same interest. The seventh question about how vocal cords work was added to the collective goal list on October 10. During the following two months, students did focused research on these themes while having the flexibility to switch between these areas as their interest evolved. They made posters and models to show new ideas about their focal question, and shared findings/further questions in face-to-face whole class meetings and on KF. Later, through a whole class reflection on knowledge advancement, students identified new goals in reflection of expanded aspects of their inquiry. On December 12, two new questions were identified: Why do we have respiratory system, and how do human body cells work? Interestingly, as part of the reflection on collective knowledge progress, a student proposed a question about muscles as a new big question. His peers who investigated bones suggested that this question about muscles could be integrated in the existing question about bones as the two are so closely related. On January 9, the first big question was renamed as "why do we have muscular and skeleton system?" Altogether nine collective questions, representing the shared goals of inquiry, were progressively formulated (see Figure 1) and continually investigated in the rest of the inquiry.

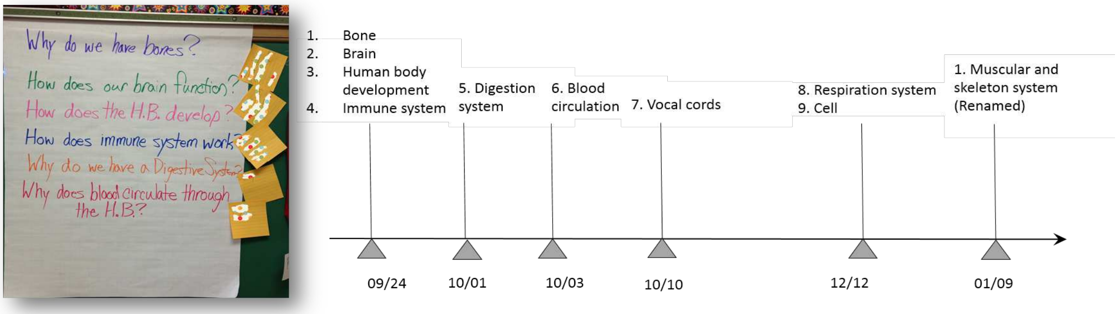


Figure 1. Evolution of shared goals of inquiry.

These goals originated from students' initial curiosities were refined and reframed through metacognitive conversations about diverse ideas and questions presented in the ongoing face-to-face and online discourse. The excerpt below shows an example of such metacognitive conversations to review existing questions and formulate collective questions. The teacher, as a co-learner, played a critical role in helping clarify initial wonderings to connect with deep domain knowledge in the area of human body research.

Teacher: So far, we have "why do we have bones", "how does the brain function?" and "how do human bodies develop?" What's that?

Student 1: Why do we have nose?

Student 2: That would be a question under the human body development…

Teacher: Is that a….Now, I'm asking you. Okay, please, please, why…is that a big branch? Or is that a smaller branch that could be added to something else? Now I have allergies. Is there any ideas that I can have the serious focus with you? I have a larger mouth, stuffing my nose, every single day. So nose, nose, nose goes where…

Student 3: Why do we have mucus?

Teacher: Mucus….Why do I have mucus? Mucus problems…They are always there, but when do you notice it? When you have mucus problems…when you were sick. So can we make a bigger idea about something like…?

Student 4: Health?

Student 5: Why do we have health issues?

Teacher: So there is a little question. Have you guys ever heard of immune system?

Students:	(together) Oh….Yes!!!
Teacher:	Is that what we were talking about? Does that sound like something that a big branch looks like…?
Students:	(together) (Nod)
Teacher:	So let's try, write down something about immune system…How could you guys phrase something about the immune system?
Student 6:	How does immune system help us?
Teacher:	Wow…All right (write it on the poster). How…… does……immune system….What's it?
Student 4:	Work?
Teacher:	(write on the poster) All right, that's pretty awesome. You guys generated the branches (pointing at the questions on the poster)… all these things.

The teacher, as well as the community as a whole, was open to including new questions from students into the list of collective goals. The emergence of the vocal cords as an inquiry area is a sound example. On October 8, student A read the book Kids InfoBits written by Beth Allen. She was really interested in the part about vocal cords and took some notes in her notebook. Even though she had signed up for the immune system inquiry, she talked to the teacher about her new interest in how vocal cords work. Meanwhile, student B who, was still hesitant about which group he should join in, read the magazine Science Spin (Primary). He took some notes about how sound is produced through air vibration. Since he was not sure about his focus question, the teacher suggested that he started with what he was working on. Student C, who had signed up for the immune system, sitting next to student B, indicated the same interest in vocal cords, with some notes taken about pitches of vocal cords based on movies on the BrainPop site. Then the teacher supported their proposal to start research on vocal cords. Student D, who had not decided a focus area, showed interest in this new question. Therefore, these four members formed into a temporary group to study vocal cords.

Content analysis of students' contributions in online discourse

To examine how collective goals guided student participation in the online discourse, we coded students' KF notes based on the collective goals. Table 2 shows the number of notes created and the number of contributors involved before and after the formation of each goal, with the date when each goal was formally added as the cutting point. For example, the question about vocal cords was identified as the seventh collective goal on October 10. Therefore, October 10 was used as the cutting point for the calculation.

Table 2: The number of notes and authors before and after the formation of each collective goal

Collective shared goals	Before the formation		After the formation	
	Notes	Authors	Notes	Authors
1. Why do we have bones (muscular and skeleton system)?	0	0	21	8
2. How does the brain function?	0	0	131	24
3. How does the human body develop?	0	0	125	24
4. How does immune system work?	0	0	194	23
5. Why do we have a digestion system?	3	3	25	10
6. Why does blood circulate through the human body?	12	11	65	19
7. How do vocal cords work?	1	1	25	11
8. How does respiration system work?	2	2	3	3
9. Why do we have cells?	17	9	60	18

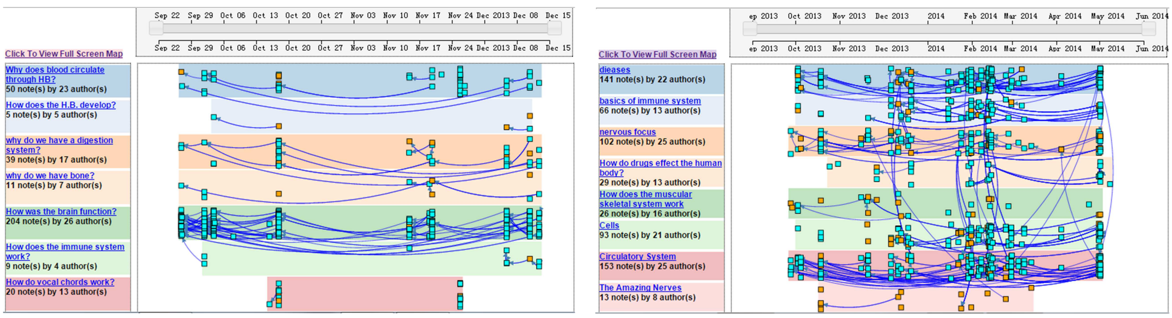
The first four goals represent a pattern of goal formulation driving subsequent discourse. The first four goals were identified in the beginning of the inquiry on September 24 based on student questions raised in face-to-face talks and written on Post-It notes. Therefore, no KF note was written before the formation of these goals. As the Table 2 indicates, these focal areas attracted intensive online discourse contributions of students. In the early phase, the contributions in each area were mostly from members of the corresponding specialized group who signed up for the research. Interestingly, as the inquiry deepened and cross-theme connections became evident, students contributed notes to discuss interrelated issues and further posted information beyond their own focal areas. This was most evident in goal 2-4 that engaged contributions from almost every student. The collective goals, which were treated as open-ended and evolving, guided the formation of specialized inquiry groups while allowing students to interact flexibly within the whole community to address interrelated issues.

The online discourse about how vocal cords work provides an example of collective goal emergence based on individual contributions specialized in a topic, opening up a line of inquiry. Before the goal about vocal cords was formally identified, there was only one member from the human body development group asking “how do we talk”. One week later, after the formation of this goal, the four members began to share findings about location of vocal cords, and how the vocal cords works through vibration. They also built on the initial question “how do we talk”. After noticing the progress of work about this goal, the contributor of the first question came back to share his experience that could be well explained with newly shared information. These contributions caught the attention of a student from the brain function group. He joined in the conversation by requesting more details about “larynx”. A girl from the blood circulation group noticed these notes and joined in this talk, asking about the relationship between the thickness of pitches and the changes of voice at different ages. Meanwhile, a member in the group asked, “Vocal cords vibrate to make sounds but what makes the vocal cords vibrate?” Another student from the human body development group contributed to the vibration issue with an explanation of air moves. With a collective focus on the same goal, progressive ideas and questions emerged with ongoing interactive discourse online, which further pushed the conversation to a deeper level.

Another interesting pattern was seen in the origin of cells as a collective goal. It emerged from the ongoing discourse across a range of topics that converged focusing on issues about cells. Before the formation of this goal, students investigating the immune system, bones, blood circulation, brain functions, and the human body development started to talk about cells in their own contexts: members from immune system group focused on white blood cells; members from the bone group were interested in how bone marrow made red blood cells; members from blood circulation group discussed the function of red blood cells; members from the brain function group devoted to how support cells protected neurons; while members from human body development group were sharing information about skin and tissue cells. As more students joined in the conversation, a collective goal was brought up on December 12. As Table 2 indicates, nine more students joined in this conversation after the formation of this goal. New members began to contribute to it by making connections to their focal area. For example, a girl from the bones group made the following note on KF: “My theory is that bones are also made of cells. Some bone cells are star shaped. How many different types of bone cells are there and what do they look like? I can’t find anything more in depth”. A new member who joined in in the later part built on previous work with this note: “The only thing that I know was the white blood cells but now I combine what student A say and student B say so now I know the red blood cells”. Those who had been in this group for a while moved onto discussion about cell itself, including different types of cells, the functions of them, and different parts in a cell. As the conversation moved to a deeper level, a student who had been doing research on cells questioned herself and wanted to know more about the jobs of different parts of a cell: “I have been researching about the parts of a cell. I would like to find out why cells need different parts, and what each part does. I will write about the important facts soon!” In the later part of their conversation, even deeper issues about DNA, RNA, and cancers were brought up: “I can’t explain what is a DNA and RNA’; “Cancer is grown out of control cell. Cancers only happen when something is wrong with your DNA your body will fix it. ”

Video analysis of ITM-aided reflection

To reflect on knowledge progress in achieving collective goals, students conducted the first ITM reflection in early January, and another ITM reflection session in late May. They engaged in metadiscourse to organize idea threads based on the collective goals and co-authored “Journey of Thinking” synthesis for each thread.



(a) (b)

Figure 2. Idea threads created in the first ITM session (a) and the second ITM session (b).

In the first ITM reflection, students worked in small groups to review contributions on KF that addressed each collective goal. In each group, students used ITM to search for notes addressing their focal topic with co-identified keywords, and screened and added relevant notes to their thread. Seven idea threads were created: 1) why do we have bone? 2) how does the brain function? 3) how does the human body develop? 4) how does the immune system work? 5) why do we have a digestion system? 6) why does the blood circulate? 7) how do vocal cords work? ITM displayed selected notes on a timeline as an idea thread (see Figure 2a) and further retrieved authors involved in this work, with options to show build-on connections over time. For example, the thread created for circulatory system included 50 notes contributed by 23 authors. In the early phase of inquiry, students wrote several notes about this question. However, no contributions were made from mid-October to mid-November. While in December, they came back to deepen ideas in this thread.

In the second ITM session near the end of the school year, students reviewed idea progress focusing on areas that had active contributions since the first ITM. Five emergent groups formed to set up and review idea threads using ITM focusing on the muscular and skeletal system, nervous system, immune system, circulatory system, and cells. When working on the keywords to search notes on KF, students focusing on the nervous system and immune system found they had rich contents addressed, so they decided to break down into several sub-groups focusing on more specific issues. Eventually, eight threads were created (see Figure 2b): 1) how does the muscular and skeletal system work; 2) nervous focus (basics of nervous system); 3) the amazing nerves (the functions of nerves in messaging); 4) basics of immune system; 5) diseases; 6) how do drugs affect the human body? 7) circulatory system; and 8) cells. Comparing the intensity of notes created in each thread in the two ITM sessions, it is obvious that more new contributions were made after the first ITM session from early February to March. With reflective monitoring of progress in each collective goal through idea thread, students made purposeful contributions and collaborations in subsequent work.

The knowledge progress in each thread in the second session was further made transparent through the Journey of Thinking synthesis. Analysis of the Journey of Thinking suggested that the students effectively identified problems as the collective goals, highlighted conceptual advances achieved in online discourse, and identified deeper questions to be understood. Table 3 shows the joint efforts of three students from "the amazing nerves" group synthesizing the community's progress on nerves across the whole year.

Table 3: Journey of Thinking synthesis for nerves

Our problems	**Big ideas learned**	**Need to do more**
At first, we had a huge question about the brain. The question was: How does our brain function? At this point, which was basically October, we had basic ideas about the 3 parts of the brain, and the right and left side of the brain.	The glial cells protect your neurons. If your brain have too much memories it will delete a little bit of the memories. So there are enough for new memories. You right brain controls your left side of the body and your left brain controls the right side of your body. We got these new ideas as we answered the first question. Then we got VERY deep and scientific. We learned new facts: without cells there won't be a nervous system. If there is no blood circulation. The nervous system won't work. Brain is the important part of your body. However, the brain won't function without the other parts.	We obviously did not have time so far to learn everything there is about the brain. We need to learn more about how fast the brain can send messages throughout the human body and the nerves. We need to know more about neurotransmitters. We gave to learn about how those little fat cells that do something we don't know!

Discussion

In this study, the course of the whole year inquiry unfolded in an emergent and improvised manner driven by progressively expanded/deepened discourse. Students engaged in metacognitive conversations to review the ideas and questions emerged in inquiry and online discourse to formulate collective deepening goals, reflect on progress made, and plan for deeper inquiry. The analysis of the pre- and post-tests showed the productivity of the community in building deep understanding of how the human body systems work. (The productivity is also evident in our content-based coding of online discourse based on epistemic contributions, which is not reported in this paper.) The qualitative analysis provided a detailed account of the evolution of the collective deepening goals, which were repeatedly used and referred to in the subsequent inquiry to guide student participation, discourse, and progress review and sharing. The collective goals emerged and evolved through several reflective cycles: formulating an initial list of four big "juicy" questions based on diverse individual interests and questions, expanding the list to include questions about digestive systems and vocal cords based on individual and collaborative proposes, reframing existing goals in reflection of new emergent issues, and developing new conceptual goals (e.g. cells) at the intersection of different lines of work focusing on deep concepts identified. The collective goals were co-constructed and continually adapted by the community through metacognitive conversations in reflection of members' diverse input and ongoing progress. These collective goals were represented and highlighted using classroom artifacts (e.g. collective question list) to guide student attention and participation. Students referred to and revisited these goals in classroom discussions, formed into flexible topic-based groups to conduct specialized research, participated in online discourse to share and discuss findings and deepening issues; and used collective questions as focuses to set up idea threads in ITM and synthesize progress made. Based on the ITM Journey of Thinking syntheses, students further created poster presentations to share knowledge within their own and with peer classrooms. These findings shed light on the possibility and processes for young students to enact high-level regulation of long-term knowledge building initiatives. Collective metadiscourse supported by ITM provides a design to support such high-level regulation for students to formulate progressive goals and reflect on progress (see also, Zhang et al., 2013, 2014). Deeper analysis of classroom videos is underway to further understand the patterns of metadiscourse and the teacher's roles.

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