"If you don't tell us, how can we know what we are supposed to do?"

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Abstract: For classrooms to work as knowledge creation communities, students need to engage in sustained inquiry and progressive discourse. The purpose of this study is to investigate how a Grade 5 science community co-constructed pragmatic structure in the form of "research cycles" of inquiry to support an emergent and progressive trajectory of knowledge building in a year-long initiative. Qualitative analysis of field notes, classroom videos, and student notebooks elaborated the emergence of research cycles assisted by the teacher. Analysis of student interviews showed how this structure was used and adapted by individual student to position and monitor knowledge progress and plan for further inquiry. Content analyses of student focal questions and online discourse indicated that students moved to more advanced research individually and made more productive contributions in the collective level.

Introduction

Knowledge creating communities achieve productivity through sustained and progressive inquiry by which ideas are continually developed, refined, and built upon, by formulating progressive questions as solutions are developed, by assuming responsibility at the highest levels rather than relying the teacher or student leader to direct their actions (Bereiter, 2002; Sawyer, 2007; Zhang et al., 2009; 2014). In knowledge-creating organizations, members collaboratively advance collective knowledge assets through sustained inquiry and progressive discourse: they engage in idea-centered dialogues involving multiple perspectives, constructive criticism, and distributed expertise; they continually anticipate and identify deeper emergent challenges and goals as solutions and new ideas are developed; they produce their tentative theories for the community; and they collectively monitor the knowledge progress in the community and coordinate actions to plan for further inquiry (Bereiter & Scardamialia, 1993; Bielaczyc & Collins, 2006; Sawyer, 2003, 2007; Valsiner & Veer, 2000; Zhang et al., 2009). For classrooms to work as productive knowledge building communities, teachers should guide students to assume all these responsibilities so as to take charge of their own learning.

The needs of education for a Knowledge Age coincide with the tenets of inquiry-based learning model (see Manlove, Lazonder, & de Jong, 2006). For decades, an extensive body of research has demonstrated its merits in transforming science classrooms (Chinn & Hmelo-Silver, 2002; Chinn & Malhotra, 2002; Magnussen & Palincsar, 2005; Schwarz & White, 2005). Meanwhile, in order to develop thorough and coherent understandings of world around them, National Research Council (2012) further emphasizes the significance of creating sustained opportunities for students to work with authentic problems and develop real ideas over a period of years rather than weeks or months. However, coherent explanations and new understandings don't emerge naturally by simply engaging students in inquiry over time (Lemke, 2001; Mercer & Littleton, 2007). For students to have cumulative learning experience of diverse activities extended in time, it's critical for them to work as active agents to position their contributions and pursuit of emergent goals as part of a longer purposeful inquiry trajectory, through which they come to make sense of the world and understand the nature of inquiry (Littleton & Kerawalla, 2012).

Existing approaches to support collaborative inquiry tend to use a structuring mechanism (Reiser, 2004), which simplifies authentic inquiry process by providing students with pre-defined tasks, assigned roles, and a set of established routines, scripts, protocols, or approved procedures to guide their inquiry activities (Fischer, Kollar, Stegmann, & Wecker, 2013; Hmelo-Silver, 2006; King, 2007; Krajcik & Shin, 2014; Lu, Bridges, & Hmelo-Silver, 2014; Weinberger, Stegmann, Fischer, & Mandl, 2007; Wells, 2001; White & Frederiksen, 1998, 2005). In these approaches, inquiry goals are broken down into a sequence of activities to be completed by students, including assuming designated roles, understanding the problems prepared by teachers or facilitators, working with small group members to accomplish sub-goals by following a prescribed sequence of activities (McNeill & Krajcik, 2012; Scanlon, Anastopoulou, & Kerawalla, 2012) or even a particular pattern of dialogue (Palincsar, 1986). These structures created by teachers or more knowledgeable facilitators are helpful in guiding short term actions when learning environments are stable and predictable (Berliner, 2011). But it is the teachers and facilitators themselves who take on the overall cognitive responsibility during the inquiry process. When students are asked to follow these procedures, little space is left for student's natural curiosity and interest to evolve into an active investigation, examination, and evaluation in a conscious manner, which greatly affects students' sustained engagement in inquiry (Flum & Kaplan, 2006; Kuhn, 2007). Meanwhile, by reducing complexity and choice, those structures are inclined to undermine high level inquiry objectives by making the pursuit of advancing students ideas peripheral (Scardamalia & Bereiter, 2006). And as situations become less certain in sustained inquiry that spans several months or years, it's almost impossible for students to adhere to those pre-defined structures, or even for teachers or facilitators to create those structures for students.

Recent research suggests an alternative approach to designing and sustaining knowledge building through principle-based, reflective structuration (Tao, Zhang, & Huang, 2015). This approach is informed by the view of collaborative knowledge building as sustained, multilevel emergent social system (Sawyer, 2007; Stahl, 2013; Zhang, 2012; Zhang et al., 2009) and the social structuration theory (Giddens, 1984). New knowledge is continually generated over time through dynamic interactions across the social levels of individuals, small-groups, and community. In this social learning system, the whole course of learning unfolds in an emergent manner driven by the joint interplay of the teacher and students (Wenger, 2010). Creative knowledge practices require continual adaptation and invention beyond recurrent routines. In this context, members not only regulate their individual and joint actions based on existing structures, but also adapt and create new structures when needed to support their collective work. They contribute to framing what needs to be created, how, in connection with whom, and continually formulate deeper problems and goals as solutions are developed (Bereiter, 2002; Sternberg, 2003). Correspondingly, knowledge-creating organizations need organic and flexible structures that encourage participatory control and adaptive opportunistic collaboration (Engeström, 2008; Gloor, 2006; Williams & Yang, 1999). Therefore, the key to understanding and designing sustained knowledge building practices is through analyzing the reflective structuring of ongoing interactions that involve both continuation and dynamic change driven by student agency. This research examines reflective structuring of knowledge building practices drawing upon the social structuration theory in sociology (Giddens, 1984) and communication (Poole, Seibold, & McPhee, 1985), including its later development by Sewell (1992) who emphasized agency-driven transformation of practices. The purpose of this study is to investigate how a Grade 5 science community co-constructed pragmatic structure of inquiry to support an emergent and progressive trajectory of knowledge building in a year-long initiative.

Method

Classroom Contexts

The study was conducted in a grade five classroom with 19 students from upstate New York in 2014-2015. The students investigated human body systems with Knowledge Forum (KF). Knowledge building practices in the classroom integrated individual and small group reading, whole class face-to-face conversations, individual and small group modeling and demonstrations, and student-directed presentations. Major questions and findings generated through these activities were contributed to KF for continual discourse. During their process of inquiry, with support from the teacher, students reflected on how they had been/should be doing their inquiry and co-generated a model of "research cycles" to guide their work. The research cycle highlighted important actions, including asking question, doing initial research, contributing online, developing initial theories, doing deeper research, revising theories, sharing with the class, leading to deeper questioning (see Figure 1).

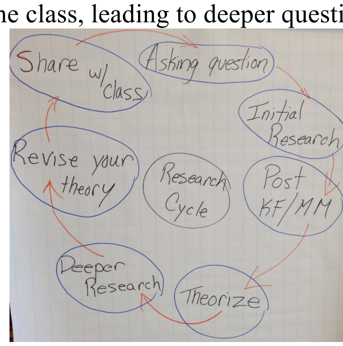


Figure 1. Collective Research Cycle Co-generated by the Teacher and Students.

Data sources and analyses

To understand the emergence of the "research cycles", we conducted qualitative analysis with rich classroom data. We began with a thorough examination of field notes taken by the first author which recorded classroom activities in the whole year. This close scrutiny yielded the discovery of key events. We then selectively zoomed into these relevant classroom moments to understand the interactive processes by which the research cycles were constructed, adapted and used. Classroom videos capturing these moments were transcribed and analyzed using a narrative approach to video analysis (Derry et al., 2010). Meanwhile, pictures of students' notebooks and artifacts (small group research cycles) created by students provided additional information about the processes at the individual and small group level related the formation of research cycles.

In order to understand how students used the pragmatic structure in their inquiry, we interviewed seven students who agreed to share their opinions about their inquiry at the end of the school year. The interviews were transcribed, analyzed with open coding (Charmaz, 2006), and interpreted using a descriptive narrative method (Gläser & Laudel, 2013).

Formulating progressively deeper questions is a critical component of the student-generated research cycles. Therefore, to see whether individual students moved to a more advanced level of inquiry, we compared each student' focal research questions in September and May with a "structure-behavior-function" (SBF) framework (Hmelo-Silver & Pfeffer, 2004; Hmelo-Silver et al., 2007). Questions in search of deep understandings about human body systems need to go beyond factual information about the body parts to focus on the processes by which the parts work together to achieve their functions. Two raters independently coded 17 students' research questions, resulting in an inter-rater agreement of 97.1% (Cohen's Kappa=0.95).

To examine relationships between the actions in the research cycles and students' contributions to the collective discourse, we further conducted content analysis (Chi, 1997) of students' online discourse using the coding scheme in Table 1. In line with the essential actions on the inquiry cycles, the level 1 categories include questioning, theorizing and explaining, collective evidence and referencing sources as two ways of doing research, and connecting/integrating as an outcome of knowledge sharing. Under the level 1 categories, a set of codes capture more specific productive discourse patterns (Hmelo-Silver, 2003, Zhang et al., 2011): factual question vs. explanatory question; idea initiating wonderment vs. idea deepening question; intuitive explanation, alternative explanation vs. refined explanation, and evidence. Two raters independently coded 20% of the notes (874 in total) to assess inter-rater reliability, which was 94.7% in agreement (Cohen's Kappa = 0.94). Then we made comparison between the number of notes in each contribution type before and after the negotiation of the research cycles. Because of the holidays in November, December and Jan, preparation for the state tests in the whole April as well as their preparation for final project in May and June, the time they worked online before and after the construction of research cycles are basically equivalent.

Table 1: Epistemic coding scheme for discourse in Knowledge Forum.

Level 1	Level 2	Description
Questioning	Factual question	Questions asking for factual information
	Explanatory question	Questions that need detailed explanation.
	Idea initiating wonderment	A question searches for general information about a theme-based area.
	Idea-deepening/ elaborating question	A question that searches for deeper and more specific information on the basis of ideas and understandings that have already been discussed.
Theorizing / explaining	Intuitive explanation	A statement uses an intuitive theory to explain certain phenomenon or issue based on personal experience using informal language.
	Alternative explanation	A statement that suggests a possible different explanation in disagreement or conflict with existing explanation(s).
	Refined explanation	A statement that presents elaborated explanation that involves justification and elaboration of specific processes/mechanisms.
Evidence		A posting that describes experiments, observations, and other sources of data to support or challenge an explanation.
Referencing sources		A posting that introduces information from readings/websites/experts and uses the information to deepen ideas and generate questions.
Connecting and integrating		A posting that connects different ideas to generate a synthesis, summary, high-order conceptualization, or integrated solution.

Findings

The emergence of the collective structure

To understand the emergence of the "research cycles", we conducted qualitative analysis with rich classroom data, including field notes, classroom videos, pictures of students' notebooks, and artifacts created by students. Analysis of these data yielded three main phases involved in the emergence of the research cycles (see Figure 2):

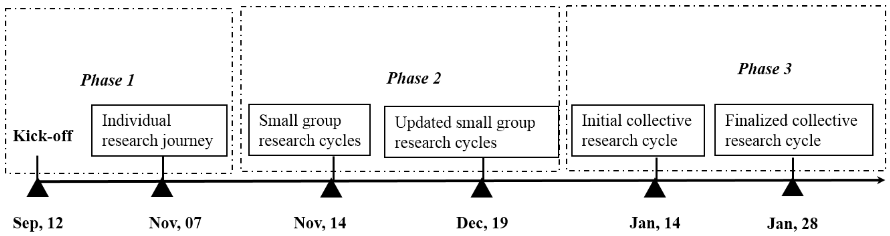
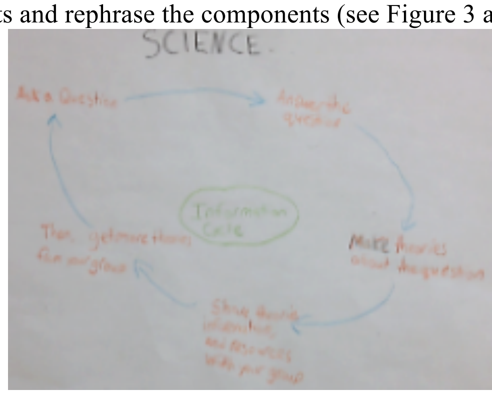


Figure 2. Evolution of Research Cycles.

Phase 1- Reflection on individual journey of inquiry: In early November, when the teacher noticed students actively commented and built upon each other's ideas, he brought up the concept of research journey. With two questions provided by the teacher, each student reflected reflect on their own learning journey, in terms of where they were now and where to go next. They first shared and discussed their answers in small groups. Then they organized a whole class discussion to share the reflection.

Phase 2- Co-generation and improvement of small group research cycles: Students worked in small groups and generated group-based research cycles according to their individual reflection on research journey and experience in collaborative inquiry. Most of the research cycles generated by small groups included some similar components. Each small group used their own model to reflect on their knowledge building work and decided what they needed to do for deeper inquiry. After gaining deeper experiences with the inquiry process in small groups, the five small groups revisited and updated their research cycles in mid-December, mostly to refine the sequences of the components and rephrase the components (see Figure 3 and 4).



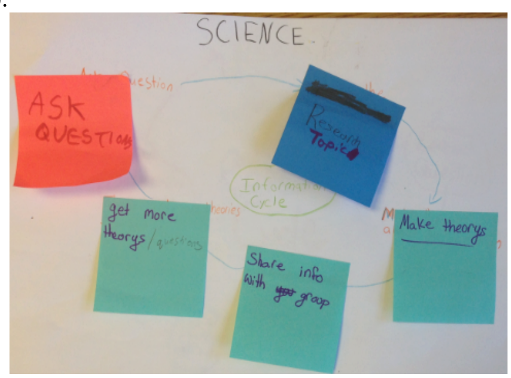


Figure 3. Original Small Group Research Cycle

Figure 4. Updated Small Group Research Cycle

Phase 3- Synthesis of small group research cycles into the collective research cycle: In January, the teacher encouraged students to reflect on their research in the past months and develop a collective model of research cycle that everyone can use to guide new research in the spring semester. Students first identified the first three components: asking a question, initial research, and sharing online or in whole class meetings. Then they proposed and included four more components: theorize, research deeper, revise theories, and share within the class (then start over), leading to the collective cycle shown in Figure 1.

By reflecting on their initial journeys of research as individuals, small groups, and a whole community provided a dynamic social context by which the pragmatic structure of the research process emerged and was reified as formal research cycle. Reflection at the individual level directly connected with students' earlier intuitive way of doing science inquiry and contributed to the basic components of the inquiry process. The experience of engaging in collaborative inquiry and constructing small group research cycles gave them a chance to review and update their individual "schema" about science inquiry. An initial small group research cycle (see Figure 3) was drafted by ordering the components from individual reflection and inquiry experience. Small groups changed the order of those components and rephrased them in a more scientific way after the application of it for one month (see Figure 4). But as their inquiry went deeper, they had the experience to conduct deeper research and revise their existing theories, more components were added to the collective research cycle, to make it as a shared schema for progressive inquiry.

Teacher's strategies in facilitating the emergence of the collective structure

Analysis of classroom talks and interactions revealed two strategies adopted by the teacher in facilitating the generation of the research cycles. First, the teacher actively engaged in the reflection process as a responsive facilitator by asking metacognitive questions to stimulate productive thinking and sharing. In addition, the teacher monitored emergent practices of inquiry in the classroom that appropriated the collective research cycles, and purposefully identified productive examples to make the research journey more accessible for all students.

Students' adaptive use of the collective research cycle

In order to understand how students used the pragmatic structure in their inquiry, we interviewed seven students about their inquiry at the end of the school year. All the seven students interviewed thought the research cycle was helpful in guiding their knowledge building process. Analysis of their reflective comments on how they specifically used the research cycle revealed two categories: (a) following the cycle; and (b) adapting the cycle for their own use. A few of the students followed all the components in order as they investigated different research topics. Other students modified the collective cycle in different situations.

Knowledge building achievements in individual and collective level

We coded students' individual focal research questions in September and May with the "Structure-Behavior-Function" framework (Hmelo-Silver et al., 2007). The proportions of students' questions differ significantly between September and May (χ^2=14.97, df=2, p=.001). To measure the collective knowledge advancement, we further analyzed how students made various types of knowledge-building contributions (Zhang et al., 2011) as reflected in their online discourse before and after the emergence of the research cycles (see Table 2). Analysis indicated that before the construction of the collective research cycle, the most visible online contributions posted relatively broad explanatory questions about the body systems and generated intuitive explanations. After the negotiation of the research cycles that systematically highlighted a diverse range of specific knowledge building actions, students had a large number of posts raising idea-initiating questions and idea-deepening questions, elaborating ideas using referential sources of information, using evidence to support or challenge ideas, providing alternative explanations, and connecting and integrating ideas to develop coherent understandings.

Table 2: Students' knowledge building contributions in Knowledge Forum.

Contribution Type		**Before research cycles**	**After research cycles**
1. Questioning	Factual question	8	8
	Explanatory question	45	18
	Idea initiating question	17	48
	Idea-deepening question	24	70
2. Theorizing/ explaining	Intuitive explanation	110	114
	Alternative explanation	13	34
	Refined explanation	31	29
3. Evidence		18	88
4. Referencing sources		24	167
5. Connecting & integrating		1	7

Discussion

This study examined how students worked together to co-generate collective pragmatic structure in the form of research cycles with facilitation from the teacher and used the structure adaptively to sustain productive knowledge building over a school year. Focusing on their initial questions and interests about human body systems, students first conducted inquiry based on their intuitive sense of the process of research as it had been loosely practiced in their prior schooling experience. As Table 2 suggests, their actions of inquiry typically involved asking broad questions about human body systems, generating intuitive explanations, and finding refined ideas using information sources. Reflecting on their initial journeys of research as individuals, small groups, and a whole community provided a dynamic social context by which the pragmatic structure of the research process emerged and was reified as formal research cycles. The emergence of the research cycles underwent several iterative cycles of reflective talks: students reflected on their journeys of research in small groups, and bootstrapping their reflective discussions, they made efforts to "peek" into the practices of scientists to adopt essential components of research. The research cycles of the small groups were shared and discussed in a whole class discussion and used by the small groups for a period of time. Based on their trial of their research cycles, students then reconvened as a whole community to generate a collective model of research cycles, which was presented on a poster, as a structure-bearing artifact. The teacher facilitated the multiple cycles of reflective talks, encouraging students to reflectively identify important features of research from their own ongoing knowledge building practices, negotiating the meanings of the components and their connections, while making connections with the practices of expert scientists. He hung the research cycle model on the wall to ease its use and further observed how his students directed their inquiry in reference to the research cycles and identified examples of emergent practices (e.g. note-taking strategies in line with the research cycles). Students referred to components of the research cycles in classroom talks to communicate their work, and used the cycles to reflect on what they were doing and what they needed to do in the next steps. They acted in accordance with the research cycles to conduct their research and adapted the cycles flexibly when they needed in specific situations. Through the intentional and adaptive use of the research cycles as a pragmatic structure of inquiry, students conducted sophisticated knowledge building practices individually and as a community. Personally, they make systematically efforts to work on deepening questions in search of mechanisms underlying major functions of the human body. The profile of knowledge building contributions in the community's online discourse was diversified in reflection of important components of the research cycles, such as asking questions to deepen existing ideas and initiate new ideas, elaborating ideas using information sources, collecting evidence, and providing alternative explanations.

Taken as a whole, the results suggest two-way ongoing interactions between the ongoing knowledge building practices of the members and the collective structures of the community: the collective structures emerge from members' ongoing practices and interactions through reflective monitoring and meta-talks, and become alive and influential through members' subsequent talks about and purposeful use of the structures. Clearly, deeper research is needed to better understand such dynamics that are essential to knowledge building.

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Acknowledgments

This research was sponsored by the National Science Foundation (IIS #1441479). We would like to thank the students and teachers at Guilderland Elementary School for their creative work.