Co-Framing Shared Epistemic Objects of Inquiry to Support Knowledge Building Over a Whole School Year

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Abstract: This study explores how fifth graders and their teacher co-constructed shared epistemic objects as collective directions of inquiry to sustain knowledge building about the human body system with Knowledge Forum over a whole school year. Qualitative analyses of observation notes, classroom videos, teacher reflective journal, and student artifacts elaborated the reflective processes and interactive roles of the teacher and her students to co-frame shared directions of inquiry as the knowledge building unfolded. Qualitative and quantitative analysis of students' survey, interview, research journeys, and online discourse showed how the reflective structuration of epistemic objects helped to sustain and deepen their inquiry over time. These results, together with findings from our previous studies, shed light on agency-driven reflective structuration as a self-sustaining mechanism to guide and sustain principle-based knowledge building practices without extensive pre-scripting.

Introduction

Over the past two decades, major advances have been made to elaborate the socio-cultural and cognitive processes of collaborative inquiry and knowledge building (e.g. Bell & Linn, 2000; Edelson & Reiser, 2006; Hakkarainen, 2003; Hmelo-Silver, 2004; Järvelä & Hadwin, 2013; Roschelle, 1992; Zhang et al., 2007). Despite the conceptual and technological advances, we, as a field, still face the challenge of bringing sustained collaborative inquiry and knowledge building into classrooms to transform educational practices. Underlying this practice gap is a conceptual challenge about how student-driven collaborative inquiry should be organized and supported. This challenge is even more significant for collaborative inquiry programs that require students to enact high-level agency and responsibilities. Research to support collaborative learning and knowledge building has led to a core debate between scripted versus non-scripted approaches (Bereiter et al., 2017) and between procedure-oriented versus principle-based open-ended designs (Zhang et al., 2011). A scripted approach to collaborative inquiry guides and scaffolds learners using carefully designed scripts of collaboration and inquiry for students to use and internalize (Fischer et al., 2013). Such scripts specify, sequence, and distribute various task operations and activity procedures among learners in order to guide them to engage in effective interactions (Kirschner & Erkens, 2013). A non-scripted approach to inquiry, such as the Knowledge Building pedagogy (Scardamalia & Bereiter, 2014), adopts an open-ended, principle-based (as opposed to procedure-based) framework by which teachers and students dynamically co-construct the classroom flow of inquiry as their work proceeds, guided by a set of core principles. At the heart of this debate is an often-polarized tension: At one end is the critical need of guiding structures for inquiry to be effective, and at the other end is the importance of student epistemic agency in creative work and dynamic collaboration.

While the principle-based approach to knowledge building holds promise for enhancing student high-level agency in creative work and collaboration, implementing knowledge building in broad classrooms still faces the challenge of how the fluid, open, and agency-driven processes of inquiry becomes socially organized and pedagogically supported. Reconciling the tension between student agency and structures, we identified *reflective structuration* as a self-sustaining mechanism through rich analyses of productive knowledge building communities (Zhang, 2013; Tao & Zhang, 2017; Tao et al., 2015; Zhang et al., 2011). Knowledge building communities engage in dual-layer construction: As students engage in deep inquiry and discourse to advance content-focused questions and ideas, they also work with their teacher to generate and adapt collective structures of inquiry to guide and support their collaboration and contribution. These structures provide shared expansive frames—reified using various classroom resources and artifacts—of the unfolding directions of inquiry and ways in which the community should operate. The co-constructed structures are further used by the community to guide individual and collaborative actions, leading to further structural elaboration and adaptation of the inquiry-based practices.

A key aspect of the agency-driven structuration process is to structure what the community should investigate: collective foci, goals, and directions for sustained inquiry. Drawing upon sociologist Knorr-Cetina (2001), we refer to the things of investigation as "*epistemic objects*," which "*are at the center of a research process and in the process of being materially defined*" (p. 181), signifying the lacks, needs, and insufficiencies

of knowledge that lead to unfolding strands of knowledge practices. Knowledge workers direct and sustain their knowledge practices by continually identifying new epistemic objects and projecting possible epistemic moves upon them. It is a critical challenge to understand the processes by which a community frame shared objects and unfolding directions of inquiry to sustain long-term inquiry, without extensive pre-scripting from their teacher.

Drawing upon our previous studies (Tao & Zhang., in press; Tao et al., 2015), the current study aims to provide a more detailed account of how members of a Grade 5 science classroom (the teacher and her students) worked together to frame/re-frame a connected set of epistemic objects as the focus of knowledge building about human body systems over a whole school year. Our research questions ask: How did the community identify and frame the objects of inquiry to sustain its knowledge building over time? How did students use the structures to support their participation, with what impact on their knowledge building practices?

Method

Classroom contexts

This study was conducted in a Grade 5 classroom at a public elementary school, with 21 students who were around 10-to-11-year old. Students investigated the human body systems as the focal theme of their science curriculum, with two hours' science lesson each week. The teacher had two years of experience with the knowledge building pedagogy. Instead of following specific inquiry themes, questions or procedures prepared by the teacher, students were expected to work with their teacher's facilitation to co-identify problems of inquiry and conduct spontaneous actions to address the problems as their inquiry proceeded. The inquiry process unfolded as an open and dynamic process based on student-generated questions, which gave rise to emergent shared directions for further inquiry. Knowledge building in the classroom integrated individual and small group reading, whole class discussions, individual and small group modeling and demonstrations, and student-directed presentations. Major ideas, questions, and findings generated through face to face knowledge building activities were contributed to Knowledge Forum (KF) (Scardamalia & Bereiter, 2014), an online collaborative knowledge creation platform, for continual discourse.

Data sources and analysis

Analyses of classroom observations, videos, and the teacher's reflective journals

To answer the first research question, we conducted qualitative analyses of rich classroom data. The first author observed each science lesson, took detailed observation notes as well as pictures of important artefacts created by both the students and teacher, and video-recorded major classroom activities over the school year. After scrutinizing the classroom records, we zoomed into the specific episodes when the classroom generated a map of inquiry objects as documented in the classroom artefacts and videos. Videos related to the co-generation of the objects of inquiry were transcribed and analyzed using a narrative approach to video analysis (Derry et al., 2010). This analysis was further supported by the teacher's weekly reflection journals.

Analyses of students' survey and interview about their use of the inquiry objects map

To understand how the collective objects map support students' further inquiry, we conducted a student survey in mid-March and a student interview at the end of the school year. The student survey was made up of two open-ended questions: 1) How did the collective mapping processes help your science inquiry? and 2) In what ways can you use the collective objects map to support your further science learning? The student interview focused on the specific ways that students actually used the map to guide their subsequent inquiry. We conducted qualitative analyses of these two sources of data together using an open coding method (Charmaz, 2006).

Analyses of the students' research journey reflection and their online knowledge building discourse

To examine the impact of reflective structuration of collective epistemic objects in driving sustained inquiry, we collected the following data from different sources and analyzed them with a content analysis method (Chi, 1997): 1) students' individual reflection on their research journey aided by the collective objects map about the epistemic objects each of them had investigated and learned from their peers in late April; and 2) students' online knowledge building discourse in KF. We coded students' posts over the school year with a five-category coding scheme, which captures productive discourse patterns (*1=questioning, 2=theorizing, 3=evidence, 4=referring resources,* and *5=connecting and integrating*) (Zhang et al., 2011). Two raters independently code 20% of the notes to assess interrater reliability, which was 93.64% (Cronbach's Alpha =.95). For those posts which were coded as "*theorizing*", a further content analysis was conducted to assess scientific sophistication of "*theories/explanations*" developed by students based on a 4-point scale (*1=pre-scientific, 2=hybrid, 3=basically*

scientific, and 4=scientific), which was verified in our previous research (Zhang et al., 2007). Two raters independently 20% of the notes labelled as "theorizing", resulting in an inter-rater agreement of 91.43% (Cronbach's Alpha =.92).

Results

How did the community identify and frame the objects of inquiry to sustain its knowledge building over time?

Qualitative analysis of rich data identified the reflective processes the community worked together to co-generate shared epistemic objects (see Fig. 1). These include (a) co-formulating collective wonderings (e.g. how does the brain work) based on students' individual questions; (b) re-framing, adapting and updating existing big wonderings to include new objects of inquiry; (c) deep search, framing, and collective mapping of interrelated epistemic objects as the shared focus of the community's unfolding inquiry and discourse; (d) individual and small-group reflection and planning for specialized inquiry aided by the collective objects map. Table 1 summarizes the major actions of the teacher and students, and the collective structures co-generated and adapted. Details of the reflective processes as well as the major actions of the teacher and her students are described below.

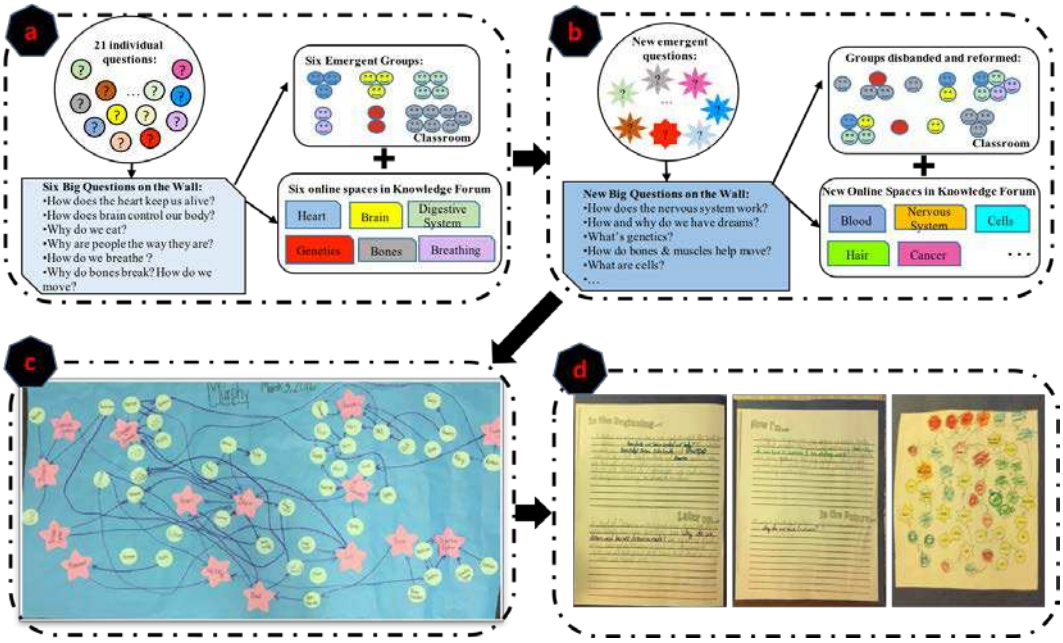

Figure 1. The reflective structuration processes that the community co-frame shared directions of inquiry.

(a) *Co-formulating collective wonderings based on students' individual questions.* Prior to the beginning of the school year, the teacher identified the human body systems as the focal topic of the school based on their school district's curriculum. The inquiry began with ten out-door games designed by the teacher and another Grade 5 science teacher, aiming to engage students in various activities related to different human body systems. These activities triggered students' initial interests. When they returned to the classroom, the teacher organized a whole class conversation to share their experiences. After that, each student wrote down the question they were most interested in on a sticky note. They also decided together to "*think about their questions and find books that related to their questions to read*". When they met again to share the progress, each student brought one book about their question. The teacher suggested each student to prepare a post-it sticker and write down the following information on it: "Name", "My question", and "Body parts (I'm working on)". Then students pasted the sticky note on the book they chose, searched for the students who were working on related questions about the same body parts. In this way, students were automatically "grouped" into six small groups. These small groups then worked together to co-frame a bigger question to include each member's question. In late September, the initial six big questions were identified and hanging on the classroom wall. Corresponding separate spaces were set up in KF, too.

Table 1: Processes by which the community co-generated collective objects about what they should investigate

Processes	Teacher and Students Input to the Reflective Processes		Objects Created
(a)Sept., 2015	**Teacher**: • identified the human body as the theme for science; • prepared 10 outdoor games involving various human body functions; • facilitated whole class discussions to reflect on experiences about outdoor human body activities; • provided template for students to group questions.	**Students:** • participated in games to experience body functions; • shared experience and questions in the class reflection; • searched for books about their questions, found peers with the similar questions to work together; • formed 6 small groups based on interest and created a big question as the focus of inquiry.	• 21 individual research questions; • 6 big questions recorded on a chart paper and later pasted on the classroom wall; • 6 small groups formed and corresponding workspaces in KF
(b) Oct.– Jan.	• ongoing noticing of inquiry progress about each big wondering questions; • designed templates for individual students and small groups to reflect on knowledge progress and plan for further inquiry; • facilitated group and collective discussion to share knowledge.	• worked individually and in small groups to address the focal questions, reflect on knowledge progress and plan for further inquiry; • generated more new questions of inquiry; shared them in whole class reflection and online; • formed new groups to work on new topics.	• new individual and group questions emerged from unfolding inquiry; • new big questions; • new workspaces created in KF for online knowledge building discourse.
(c)Feb.– Mar.	• monitored progress of inquiry, facilitated sharing of knowledge advancement; • prepared an incomplete list of objects of inquiry for individuals to review their journey of inquiry; • facilitated whole class reflections to map out all the objects of inquiry and connections.	• shared knowledge progress in their focal wondering questions, share new knowledge and questions in face to face discussion and online; • reflect on individual research journey and the connections among the objects each student investigated; • reflect on all the objects investigated and the connection among them.	• individual journey of inquiry about objects student investigated and the connections; • a collective objects map; • newly identified objects.
(d)April – Jun.	• designed template for students to reflect and plan for inquiry; • organized collective reflection with the map to share new knowledge and emergent objects.	• reflected on individual research journey and the new ideas learned; • decided what to work on with the collective map, and find peers with the same interests to work with.	• individual journey of thinking folder; • newly identified objects of inquiry.

(b) *Re-framing, adapting and updating existing big wonderings to include new objects of inquiry.* Students continued their inquiry from October to December. The teacher, with support from our research team, designed various reflection templates for individuals and small groups to reflect on where they were in their inquiry, new knowledge gained, and where they should go next. When small groups felt they were done with their research about one topic, they asked their teacher for a time slot to hold a whole class meeting to share their knowledge progress and emergent questions of inquiry with peers. New epistemic objects of inquiry were generated based on new questions from ongoing inquiry. During these three months, initial small groups finished the work on their original focal objects disbanded and re-formed to work on new unfolding big questions (See Fig. 1b). New emergent groups formed accordingly to continue their research. Corresponding new spaces were set up in KF for their online knowledge building discourse, too. In late January, all students moved onto new objects of inquiry.

(c) *Deep search, framing, and collective mapping of interrelated epistemic objects*. In February, small groups reflected on knowledge progress in new inquiry areas. As more and more new questions were proposed, the community decided to reflect on all the objects they'd investigated so far. Supported by an incomplete list of epistemic objects identified by the teacher, each student started a review of individual inquiry. Based on this individual reflection, the whole class conducted two collective conversations to identify collective epistemic objects and the connections among them. Meanwhile, emergent objects that were missing in the initial prepared list and new objects that no one in the community had worked on before were identified (see Fig. 1c). The teacher hung the collective objects map on the classroom wall for students to refer to for further inquiry.

(d) *Individual and small-group reflection and planning for specialized inquiry aided by the collective objects map*. After the co-generation of the collective objects map, students continued their work to prepare for a science symposium as a way to share all their knowledge gain with their peers, parents, and students from other Grade 5 classrooms. As a product for the symposium, each kid wrote an individual journey of thinking about all the objects they investigated and the objects they plan to research soon (see Fig. 1d). Finally, their collective reflection on where to go next led collective inquiry to more specialized objects. Some kids began to work on

the objects that were missing on the collective map, like "*kidney*". Some other kids moved onto other objects that was researched by their peer but they had not investigated yet because they wanted to know more about the human body.

While using the collective map of the inquiry objects to guide knowledge building, the community remained open and reflective about new possible directions and connections. A whole classroom conversation was held to review how the various lines of inquiry were connected. Before the collective reflection, the teacher worked with our research team to identify an incomplete list of objects investigated by all students based on their face-to-face and online knowledge building discourse. One student noticed that almost every object of inquiry connected to brain. That led to the whole class discussion with the brain as an object in the center. Other objects were added one by one based on the connections among them proposed by students. During this process, three new major objects (see the pink stars in Fig. 1c) were added/adapted (*genetics, immune systems, and 5 senses was promoted*); seven new small objects (see green circles in Fig. 1c) were identified (*O.C.D., A.D.D., red blood cells, white blood cells, pain, nails, and virus*); 25 new connections were made; as well as one "not-yet" object (*kidney*) was recognized. Below is how they identified the object "*kidney"* together through the whole class discussion.

T: *…does anybody feel like there are small concept, that green circle missing …?*

S1: *Did somebody already say kidneys?*

T: *What?*

S1: *Did anybody say kidneys?*

T: *Did anybody make anything about kidneys? You are studying it? Does anybody study the Kidney?*

S2: *I did the digestive system.*

T: *You did the digestive system?*

S2: *That goes with the digestive system, but…*

T: *But, but…are the kidneys part of the digestive system?*

S2: *Actually they are part of the excretory system.*

T: *But who is studying it? I didn't see anything about that on Knowledge Forum.*

S2: *Nobody! But the digestive system is the cause of the excretory system.*

T: *I will write down Kidney. But I really want this map to represent things we've studied and things we know. And I'm going to leave it clipped up until it's explored…*

S1: *I will study it!*

T: *You will study it? That's awesome!*

Nobody in the community studied *kidney* before. But as students mapped out all the objects related to human body systems, Student 1 (S1) noticed *kidney* was missing. When she proposed the object, her peer immediately made connections with his previous research. Even though *kidney* was postponed, this discussion successfully brought it into the community's attention. And later on in May, when S1 requested for a *Kidney* space on KF to share her research, it was officially added to the collective map as an object of inquiry.

Before the collective conversations, small groups worked on isolated objects identified by each group as their focus of inquiry, without realizing the connections among them. When kids reviewed their individual research trajectory, they realized there were some connections between the objects in their own inquiry. The collective conversation provided a chance for them to see that even though different groups were working on different objects, they were actually very "connected". See the excerpt below.

S3: *…okay, the bone connects to the bone marrow. And the bone marrow connects to the blood. [Make connections between epistemic objects of the bone, bone marrow, and the blood]*

T: *Tell us more…why?*

S3: *Because the bone marrow is located in the bone. And bone marrow makes…[Inaudible]*

T: *And the bone marrow does what?*

S3: *The bone marrow makes blood.*

S4: Crazy! It makes blood cells…???!!!

S3: Yes!

S4: Just blood cells!

T: Okay! Great.

S3 was a member in the bones group that had emerged. During their research, he found the connections among bone, bone marrow, and blood (cells). So he began his research on blood after working on bones. In the above discussion, he shared the connections with peers. S4, who had been working on the heart and blood, was really surprised to know that the work on heart and blood was actually connected to the bone research. Through this collective reflection, all the objects of inquiry investigated were connected. With this connected objects map, it is easier to monitor how different lines of inquiry connect to understand how the human body systems work together.

How did students use the structures to support their participation in knowledge building?

As summarized in Table 2, the students commented that the collective map of inquiry objects supported their science learning in two ways: 1) to position their work; and 2) to understand connections among the different lines of inquiry focusing on different human body systems. For instance, several students commented on the same point: "*…there's a lot I need to learn. I have to catch up…*" Almost every student noted the connections among different objects and human body systems: "*…basically everything is connected…*" Students commented that they planned to use the collective objects map to guide their work and decide where to go next, to add something the community was missing to make the map more complete, and to know whom to interact with to share and connect the new knowledge gained. For example, one student wrote, "*…some of the stuffs now are not researched yet…*"

Table 2: Qualitative analysis of students' survey and interview about the collective objects map

Students' survey in March (21 students)	Students' interview in June (12 students)
Q1: How did the individual and collective mapping processes help your inquiry? • helped to know where I got started, what I learned, what I'm learning, and realize that there are a lot I need to learn about/catch up; • helped to know how different body parts connect and work together as a system; *Q2: In what ways can you use the collective map to support your further science learning?* • position my work, look at the map to search for something new to work on next; • see everyone's objects and connections, and reflect on them; work on something the community hasn't investigated and share them for others to learn; • learn the connections among different body parts; give ways to connect with others and share my knowledge with them.	*Q: How specifically did you use the collective objects map in your science learning?* • with the map, it's clear that all the human body systems work together and all body parts are connected; • individually, help to position his/her work and make decision about the objects to work on; • collectively, use the visualization of the objects map to see what the community has investigated, what the community hasn't researched yet, and where they should to go next; • help to know who they should connect with and where to share their knowledge online to help their peers in their research.

All the 12 students interviewed at the end of the school year suggested that the collective mapping reflection was helpful in supporting their ongoing inquiry. The epistemic object map reminded them that all the human body systems work together and all body parts are connected, "*you can see all is connected…all is connected*". Other students emphasized that the visualization of epistemic objects helped to show what they already had worked on, what wasn't researched by the whole classroom yet, as well as what they should work on next based on the connections among them. As some students have commented, *"… (with the map), I get to see if I have studied the 'blood', 'heart', and 'cells'… stuffs like that. And I can see if I can study other stuffs. With this map, I can see what I didn't study. So in the future I can go on to them…move on to study them*", *"…you can find other things to research…you can see why there are connections…*". The rest students thought the collective map of epistemic objects not only supported their own decision about what they should investigate but also who they should connect with as well as where to share their ideas in KF to help others. One student mentioned, "*…it gives me an idea of what else I can look at…and helps me to learn my topic. And it helps me know where to post in KF… it could help people who work on that topic*"

In what ways did the students engaged in productive knowledge building with the support of the collective structure?

The number of epistemic objects each student investigated/learned

In total, there were 50 epistemic objects identified by the community according to the collective epistemic objects co-generated by March. Analysis of students' individual research journey in which they summarized their overarching process of inquiry revealed that each student investigated about 10 objects (20% of the total objects) and additionally learned about 17 objects from their classmates (34% of the total objects). In total, each student gained knowledge about 27 objects (54% of the total objects) from September to March. The students focused on several specific objects for specialized inquiry with small group members or individually and at the same time developed a reflective sense of the community's inquiry in other areas for mutual learning and connection.

Content analysis of student online knowledge building discourse

First, we coded the Knowledge Forum notes based on patterns of student contributions (see Table 3). Among all the 607 notes posted by students over the school year, more than one fourth of them (26.85%) involved questions. They also theorized their initial ideas into explanations (46.29%). In the later part of their inquiry, when they identified new objects of inquiry they had little knowledge about, they tended to contributed some relevant information from websites or books about the object first (21.09%), which helped them go deeper in investigating that object.

Table 3: Student contributions in KF over the school year

Types	Questioning	Theorizing	Evidence	Reference	Integrating
Notes	163	281	24	128	11
Percentage	26.85%	46.29%	3.95%	21.09%	1.82%

The understanding of each focal object were further coded based on scientific sophistication to examine the extent to which students' explanations align with a scientific framework of human body systems (see Fig. 2). Specifically, the rating of ideas about all the focal objects were between "*3 – basically scientific*" and "*4 - scientific*" (*M*=3.09; *SD*=0.52). Compared with the initial notes they wrote in September and October about various epistemic objects (*M=1.6; SD=0.55*), which was between "*1 – pre-scientific"* and "*2 – hybrid",* students' knowledge about focal objects of inquiry were deepened significantly.

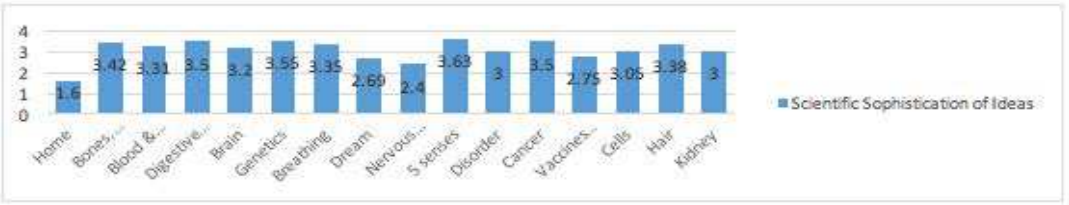

Figure 2. Rating of students' online discourse about the various objects of inquiry based on scientific sophistication.

Discussion

This study investigated the process of reflective structuration to co-frame shared epistemic objects of inquiry as a way to guide and sustain the knowledge building in a Grade 5 science classrooms. First, we documented the reflective processes by which the teacher and students worked together to frame their shared directions of inquiry over time. The collective structures emerged and evolved through several reflective cycles with the interactive input from students and their teacher, including: (a) appropriating existing structures (e.g. curriculum topic) from the school contexts and prior practices and teacher "seeding" of potential directions through inquiry activities and resources; (b) generating and reviewing diverse individual interests and questions to construct an initial list of six overarching questions; (c) using the wondering questions to guide initial personal and group research and expanding the wonderings accordingly, (d) using updated structure to guide further research, and co-reviewing and mapping epistemic objects emerged from the inquiry, and (e) further using the map of epistemic objects to plan and guide specialized inquiry. Analyses of student' survey and interviews how students used the collective structure to support their science learning with purpose. Content analyses of student survey, interview, and online knowledge discourse revealed how reflective structuration of epistemic objects contributed to students' sustained deepening knowledge building practices. Deeper analysis of student interview is underway to examine the processes of how small groups and individuals identify each focal epistemic objects of inquiry that contributes to the collective structures of inquiry. These results enrich findings from our previous studies, elaborating reflective structuration as a self-sustaining mechanism to guide and sustain principle-based

knowledge building practices without extensive pre-scripting. Based on the reflective structuration framework, we have created an upgraded design of the Idea Thread Mapper software that works with Knowledge Forum to help knowledge building communities co-structure their inquiry processes over time for connected and sustained knowledge building (Zhang et al., 2018).

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