**Literacy for Knowledge Building in Two Partnering Science Classrooms**

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**Abstract:** Using an interactional ethnography approach, this study analyzes student literacy practices in two Grade 5/6 classrooms that engaged in a science inquiry organized based on the Knowledge Building pedagogy. Students studied human body systems for 10 weeks with the support of Knowledge Forum. While students conducted collaborative inquiry in each classroom, a shared meta-space was available for cross-classroom collaboration. Analysis of classroom observations, interviews, and online discourse elaborated five core features of literacy for knowledge generation, which integrates reading, writing, and dialogue across multiple inquiry forms, media, and discourse spaces for sustained knowledge building.

**Introduction**

In an open informational world with constant changes, education needs to prepare students as critical knowledge consumers as well as knowledge generators, who can work with multiple sources of information to develop creative solutions to challenging problems. As a specific change, the pervasive use of digital technologies has transformed traditional reading and writing, changing from reading single source documents for comprehension to reading across sources, forms, and media platforms for creative problem solving (Leu et al., 2004; Liu, 2014; Goldman & Scardamalia, 2013). In reflection of these changes, education reforms call for efforts to develop productive literacy that supports knowledge generation in different subject areas (Council of Chief State School Officers, 2010; National Council for the Social Studies, 2013; NGSS Lead States 2013; Ontario Ministry of Education, 2013; Wright & Domke, 2019). To meet this demand, educators need to better understand what such new literacy looks like in practice and how to support students of various age groups in literacy engagement.

Content literacy teaching used to focus on supporting students’ role as knowledge consumers; literacy to support authentic disciplinary practices needs to additionally support student knowledge generation. What does such literacy for authentic disciplinary practices look like? Goldman and colleagues (2016) identified literacy related to five core constructs of disciplinary practices: epistemology (beliefs about the nature of knowledge and knowing); inquiry practices and reasoning strategies; overarching concepts and principles; types of texts and media in which information is represented and expressed; and discourse and language structures essential to the disciplinary practices. As literacy for science practices, students engage in close reading of science information to construct knowledge that involves multiple representations, synthesize information from multiple sources, construct explanations of various phenomena, justify and critique explanations using science principles and evidence, and understand the nature of scientific discourse. These core constructs represent key features of “reading for understanding” that supports evidence-based argumentation using multiple information sources.

Complementing the above framework that focuses more on reading, researchers underline writing and dialogue as tools of disciplinary inquiry (Applebee et al., 2003). Reflecting on how technology transforms reading and writing, Bereiter and Scardamalia (2005) proposed the concept of dialogic literacy as an alternative to print literacy. Dialogic literacy refers to “the ability to engage productively in discourse whose purpose is to generate new knowledge and understanding.” (Bereiter & Scardamalia, 2005, p. 758) Such discourse involves careful and genuine listening, understanding different perspectives, building on others’ ideas, developing common ground, and negotiating new ideas and challenges beyond the status quo. Researchers further emphasize the shift of reading, writing, and sensemaking in networked environments. A group of researchers (Liu, 2014; Thomas et al., 2007) developed the concept of trans-literacy: the ability to read, write and interact across a range of platforms, tools and media from signing and orality through handwriting, print, to digital media and social networks (Thomas et al., 2007). Given the pervasive use of digital and interactive environments, researchers call for efforts to incorporate trans-literacy as an important part of disciplinary literacy (Goldman & Scardamalia, 2013). Such high-level literacy is essential to scientific sensemaking in which students not only comprehend given information but also continually identify problems of understanding, search for and work on potential ideas, and develop coherent explanations that make sense (Odden & Russ, 2019).

This study investigates disciplinary literacy in a student-driven, open-ended inquiry organized based on the Knowledge Building (KB) pedagogy. KB aims to transform classrooms into knowledge-building communities in line with how knowledge creation takes place in the real world (Scardamalia & Bereiter, 2006). Students not only work on pre-defined problems and tasks, but also identify new and deeper problems based on their interests...
and needs. The space of problems continues to evolve as student understandings advance, driving ever-deepening inquiry processes. Networked environments, such as Knowledge Forum (KF) (Scardamalia & Bereiter, 2006), are used to support knowledge building discourse and processes. KF provides a collective knowledge space that gives student ideas a public permanent representation. Students contribute to ongoing conversations by sharing and building on each other’s ideas. They continually identify new/deeper problems while their understanding deepens. Recent research further expands student interaction and collaboration to a larger social context. Students not only collaborate with their own classmates but also share their knowledge advances in a meta-space accessible to a network of classrooms (Laferrière, Law, & Montané, 2012; Zhang et al., 2020). They engage in collaborative inquiry as members of a community who also learn from and reference the works of other communities.

Several studies have examined student literacy practices in knowledge building communities. Sun and colleagues investigated how students engaged in productive writing and reading as an integral part of their knowledge building in science and social studies (Sun et al., 2010; Zhang & Sun, 2011). Their reading practices demonstrate new features: reading for advancing the knowledge of their classroom community; reading for continual problem finding and solving; reading embedded in ongoing knowledge building discourse, both online and offline; and connecting student knowledge with knowledge built by others in the larger world (Zhang & Sun, 2011). A two-year study traced students’ online discourse during Grades 3-4 to examine vocabulary growth. Knowledge building discourse served as an authentic context for students to use and expand productive vocabulary, including academic vocabulary and domain-specific words. Their use of high-order vocabulary positively correlates with their participation rate in collaborative knowledge building (Sun et al., 2010). In a more recent study, Hong and colleagues (2020) found that children who engaged in knowledge-building inquiry outperformed those receiving traditional instruction in an assessment of reading. Beyond reading and writing of text, students also incorporated rich graphic representations in their online discourse (Gan et al., 2021).

Building on the above studies, the current study aims to depict a more comprehensive picture of disciplinary literacy for knowledge generation. Our conceptual lens integrates the above-reviewed concepts of disciplinary literacy (Goldman et al., 2016), dialogic literacy (Bereiter & Scardamalia, 2005) and trans-literacy (Liu, 2014; Thomas et al., 2007). Through the analysis of rich classroom data, we hope to capture how students read, write and interact across multiple sources, forms and spaces to advance their knowledge. As an expanded context for knowledge building, the current study included a cluster of classrooms that conducted collaborative inquiry supported by an online environment. Students engaged in cross-classroom interaction organized using a multi-layer model (Zhang et al., 2020). While members of each individual classroom pursued collaborative inquiry and discourse to deepen their understandings in a domain area, they had access to a cross-community space (“meta-space”) where they shared their knowledge advances and challenges with other classrooms that studied the same curriculum area. As a common structure for synthesizing and sharing knowledge advances, students working on a shared problem or topic co-authored a “super note” that included three sections: Questions explored, “big ideas” learned (framed as “We used to think…now we understand…”), and deeper research needed. The super notes were shared in the meta-space, as boundary objects (Star & Griesemer, 1989), to support cross-classroom discourse. In this context, our data analyses address an overarching question: What characterizes student literacy practices essential to their collaborative knowledge building? As part of this question, we were also interested in the teachers’ role in supporting student engagement of disciplinary literacy.

Classroom context

This study analyzed student literacy practices in two Grade 5/6 classrooms based on the dataset generated in our research project focused on cross-classroom collaboration for knowledge building (Zhang et al., 2020). Two teachers taught science in the two classrooms: Mr. B and Mr. M. Both teachers had multiple years of teaching experience; Mr. B was more experienced with teaching science using the KB pedagogy and technology. There were 24 students in Mr. M’s room and 23 students in Mr. B’s room.

The two classrooms studied human body systems for 10 weeks with the support of Knowledge Forum (KF) (Scardamalia & Bereiter, 2006). On an ongoing basis, students in each classroom contributed and built on each other’s ideas. With their teacher’s support, students in each classroom generated questions about the human body that stemmed out of students’ interests, put forth initial ideas, and then subjected these ideas to testing through observations, experiments, and peer discussion to improve them. They read books and online materials and conducted knowledge building talks in small groups and as a whole class to share and build on one another’s ideas. They further continued their discourse and interaction online in KF. Students in each classroom worked in their home class views (workspaces), where they read and built on peers’ ideas in the online discourse. At the same time, they had access to the “Super View” that was shared between the two classrooms. A visual was added to the Super View consisting of two trees with a number of branches where super notes about various inquiry topics could be placed (see Figure 1). As they made progress in various lines of inquiry, students created syntheses...
of their journey of thinking, which were called “super notes.” Each super note was structured using the following scaffolds: Our research topic and problems..., We used to think...Now we understand..., We need deeper research. Prior to this study, several classrooms from two schools had studied human body systems and created super notes. These achieved super notes were also shared in the Super View.

Figure 1
The “Super View” for sharing super notes (Journey of Thinking syntheses) across classrooms.

The teacher in each classroom first introduced the Super View in the third week of the inquiry when their students had generated their own questions and conducted initial research about the various topics related to the human body. Students read the Super Notes from the previous classes and reflected on what they could learn from the questions and ideas. Once students conducted deeper research in each classroom in the next two to three weeks, students working on various themes started to create super notes to summarize their progress for sharing with their own classmates as well as with the other classroom. Students from the two classrooms read each other’s super notes and discussed insights gained.

Data sources and analyses
This study analyzed student literacy practices in the human body inquiry as a telling case. Our data sources included classroom observations of the science lessons (11 from Mr. B and 8 from Mr. M), video recordings of whole-class discussions and small-group work, records of online discourse (146 notes from Mr. B’s classroom, and 243 from the class of Mr. M), 16 super notes shared between the two classrooms, and student and teacher interviews. A researcher interviewed 13 students from the two classrooms focusing on how they pursued their inquiry, created super notes, and read and learned from the super notes of the partner classroom.

Our data analysis used an interactional ethnography approach, which offers a logic of inquiry for investigating what learners do and construct in a temporal sequence of events as viewed through multiple levels of analysis (Green & Bridges, 2018). As the main data sources, we analyzed the classroom observations and video recordings in relation to student notes written on KF. A researcher observed each science lesson and created a rich documentation of the classroom events, which were indexed and mapped based on time. The data organization provided contextual information about each major classroom event observed, time and topic of the inquiry activities, highlights of student and teacher participation, and sources of data recorded. As a visual representation of what happened in student inquiry, we constructed a timeline-based map (Green & Bridges, 2018) of the learning events identified from the observation sheets of each classroom. Each learning event was then analyzed focusing on the literacy practices reflected in student work as individuals, groups, and interacting classrooms. Specifically, we used a grounded theory method (Strauss & Corbin, 1998) to code the specific forms of inquiry which students carried out, involving reading, writing, and interacting for knowledge generation. Each inquiry event was tagged based on its prevalence in the whole lesson period, ranging from a major episode (#3) to a small moment/branch of work (#2), to brief occurrence embedded in the whole classroom process (#1). We further traced backward and forward to search for empirically grounded connections between the current event and what happened before and after. Through reviewing the various forms of inquiry and discourse in the historical context of the whole human body inquiry, we identified compelling patterns (themes) that characterize how students wrote, read, and interacted during knowledge building (see Results).
Additionally, focusing on features of dialogic and trans-literacy, we conducted social network analysis to examine students’ online peer responses within each classroom (i.e., who had built on whose ideas on KF) and used content analysis to examine the quality of student super notes shared between the two classrooms. Drawing upon our prior study (Zhang et al., 2020), the analysis coded each super note based on students’ questions investigated and the complexity level of their knowledge syntheses. We also analyzed student interviews to understand how they generated super notes for cross-classroom sharing. Two researchers read and re-read the interview transcriptions, created open codes, and identified compelling themes representing various notions of super notes.

Results

Tracing diverse forms of inquiry and discourse over time

The analysis of classroom observations traced students’ engagement in various forms of inquiry and discourse that involved reading, writing, and interacting with one another for knowledge building. Due to space limit, we provide the timeline-based mapping of inquiry events in one classroom only (see Figure 2). Major activity episodes (tagged with three stars in coding) are highlighted green with three stars. Small branches of work are tagged with two stars, and very brief occurrences are marked with one star. The upper section shows the various forms of inquiry. The lower section traces the different forms of social discourse.

Figure 2
Tracing of various forms of inquiry and discourse in Mr. B’s classroom

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As the tracing of inquiry practices (upper section of Figure 2) reveals, students carried out diverse forms of inquiry to understand core issues and concepts related to human body systems, supported by rich information resources in different media and forms. Specifically, they read print materials related to their research topics as individuals or groups; searched and read information on various science websites; watched online videos; observed and analyzed visuals including 2D images, 3D models, X-ray images, and cartoons. While they made close reading and analysis, students engaged in generative processes such as taking notes of important information, ideas, and questions; generating and sharing questions as directions of inquiry; building connection across different topics and sources; using the sources to write and refine their online posts; creating personal videos to share knowledge; and playing dramas (skits) or participatory games to show how different body systems work. Over time, students continually referenced their prior works and ideas as they carried out new and deeper inquiry.

Over the course of the human body inquiry, students interacted with peers in flexible groups to discuss ideas and conduct experiments and observations. They participated in whole class knowledge-building talks to build on one another’s ideas and investigate specific questions. As an important form of classroom discussions, the teacher facilitated meta-talk: metacognitive conversations in which students shared reflections on their online
discourse or face-to-face inquiry focusing on metacognitive issues, including inquiry directions and questions, progress, plans, and ways to organize and enhance their online discourse. Drawing upon the information, ideas, and questions generated in the face-to-face activities, students wrote individual and co-authored notes on KF to have online discussions with their own classmates. Each major time slot for writing KF notes involved reading and building on peers’ notes. Additionally, special time was scheduled for students to make extensive reading of their peer notes. Beyond the regular online discourse with each classroom, students engaged in cross-classroom sharing in the later part of the inquiry through writing and reading super notes in the meta-space (Super View) shared between the two classrooms. Both regular and super notes became objects of discussion when students read and referenced specific notes and super notes in face-to-face classroom talks.

Compelling patterns of how students wrote, read, and interacted for KB
On the basis of the holistic tracking, our analysis further investigated the temporal connections among the diverse forms of inquiry and discourse, with information generated in one activity feeding to what students inquired in the next activity. A set of compelling patterns (themes) emerged characterizing how students wrote, read, and interacted for continual knowledge building.

Working across multiple sources/media of information to solve problems and deepen understanding
Connecting multiple sources and forms of information to build progressive understandings was a key aspect of student literacy practices. The observation notes documented students’ practices of using multiple sources of information such as books, online resources, videos, and images. For example, on April 7 in Mr. B’s room, “Some students are copying text from their previous Word documents. Some are using their paper notes. Some are looking into books laying around. Some are going online to find information.” On the same day, students engaged in generative activities along with their reading, including taking personal notes, generating questions, and drawing upon the sources to write KF notes (see Apr 7 in Figure 2). Their selection of reading was driven by the questions they had generated about the human body. As they read for understanding, they generated further questions. Students took notes of the information from the readings, personal understandings and questions in personal notebooks. They further reviewed their personal notes to consider what might be worthwhile to share on KF. “To write the notes, some students are using books (2 students are looking at Genes and DNA, 5 students on digestive system -> see the note on how food is processed”). One student is looking at her own notes in the binder.” The observational notes also point to teacher’s encouragement to use resources with proper practices of citing them: “The teacher is helping students to focus and enrich their ideas; he is encouraging them to use authoritative sources and reference them.” Another observational note mentions how the teacher showed students how to use videos. The needs to contribute to the community’s knowledge drove students to think further, read more closely across sources, discuss with peers, and reflect on what they had known as well as what they needed to better understand.

Integrating multiple forms of inquiry to advance knowledge
Students integrated multiple forms of inquiry and thinking, ranging from concrete experiences to personal questions, theories/explanations, video presentations, participatory games, and role play. Each form of inquiry was often embedded in the context of other inquiry activities supported by multiple sources of information. Personal experiences (e.g., dreams, injuries) were shared in the classroom talks and online discourse, feeding to student question generation and explanation/theory building. Conceptual explanations of how the body systems work were further elaborated, demonstrated, and applied through role-playing games. For example, on April 18, the teacher built on student interests to introduce a role play: “Last time you were interested in medical problems. Today, I have some medical activities for you: to do what doctors may do.” With different X-rays of the bones (and other body parts) hanging on walls around the room, students acted like doctors to figure out if the bone is broken or not. Students were given a blank form for patient notes. This form had three columns: 1 - patient’s name, 2 - injury (yes or not), 3 – name of the bone displayed on the X-ray. To support their diagnose, students could use iPads to view virtual 3D images of the human skeleton or observe skeleton models in the room. Rich conversations took place in the role-play groups and later on KF.

Navigating multiple discourse spaces for ongoing knowledge sharing and mutual build-on
The members of each class navigated multiple spaces of discourse over time, including personal notebooks, small group talks, whole class meetings, online discourse in the regular KF views of each classroom, and the Super View that served as a meta-space shared across classrooms. The teachers worked with students to develop a reflective sense of how the difference spaces could be used productively: Using personal notetaking to keep track of quick thoughts, questions, and information collected; bouncing ideas during small group and whole class
meetings; writing “worthy” notes on KF focusing on meaningful ideas and questions; and writing super notes to synthesize “big ideas” of value to broader peers. For example, on April 7, Mr. B facilitated the following meta-talk on what is “note worthy.”

Mr. B: What makes a note worthy for grade 5/6?
S1: More details and deeper questions you can research into.
S2: Don’t just say “I agree”, instead explain why you agree or disagree.
Mr. B: Do not forget to support your reasoning.
S3: Give reasoning and explain why.
S4: Add theories to your questions to explain why.
Mr. B: If you add links or pictures, describe them, explain why you put them in there. Do not forget the title of the note.

Students wrote KF notes to share their ideas, questions, and information from various sources. Their online contributions were often rooted in the various types of activities that students engaged in face-to-face, such as whole class discussions, small group talks, and experiments. They read and built on (responded to) one another’s notes for continual online discourse, which enabled ongoing idea sharing and build-on based on student need. A total of 146 notes were written by students in Mr. B’s classroom and 243 by Mr. M’s students. Figure 3 shows the sociogram of mutual build-on among students in each classroom. Each node represents a student, and each line a build-on relationship. The extensive build-on links show dialogic interactions among students in each class with everyone included.

![Figure 3](image)

Social network analysis of who built onto whose notes on KF in each classroom

**Meta-talk to reflect on the history of ideas, from the past to the present and to future inquiries**
As noted above, students engaged in meta-talk (metadiscourse) to reflect on and structure their ongoing inquiry and discourse. They shared reflections on their “juicy” questions generated by themselves and their peers; planned how they could collaborate in groups to investigate these questions, and made input on how their KF views should be organized, used and linked. As a central feature of cross-classroom collaboration, students worked in groups to co-author super notes to reflect on their journey of thinking in each line of inquiry, which were shared in the Super View. Writing and sharing super notes functioned as a specific form of metadiscourse by which students reviewed knowledge progress achieved through their online and face-to-face discourse. In the final interview, students reflected upon how they approached super note writing and reading. As the themes emerged, students considered super notes as a way to capture and share their journeys of inquiry: “It’s like one huge note that reflects on all of your ideas, and what you used to think and what you now know.” Students commented that super notes should focus on the “big ideas” they had developed, as “a summary of the big idea and knowledge basis.” As a student said, “I think it is to focus on the entire idea of the topic you are focusing on and not just the tiny details you wanna share with the whole class.” Students recognized the need to share accountable and valuable knowledge through super notes: “Well, we definitely did not include like the information that we did not know much about, because that would mean that… like if you were not sure if that was right or not, then it would not be good to include it.” They further commented that the super notes should be well-phrased and accessible: “When you look at normal notes… there maybe some spelling errors, and maybe some like grammar errors… If you look at super notes that are amazingly written and they are really simple and they help people understand what is the main focus of this super note.” Our content analysis examined the questions and ideas summarized in the super
notes. In the 16 super notes generated, students identified 32 questions for deeper inquiry, mostly searching for reasons, mechanisms, and connections. Students’ summaries of knowledge advances show a high level of scientific quality focused on offering elaborated explanations of how things work (see Zhang et al., 2020).

**Working across communities to advance personal and collective understanding**

Students read the super notes from their own and the partner classroom, reflected on the different perspectives, and identified knowledge connections and gaps. For example, Mr. B asked: “What was the idea that came from the super notes that you hadn’t thought before and that pushed your thinking further?” A student shared the following reflection on a super note she read about the brain: “Well I never really thought about what side of the brain controls what side of the body… but it turns out that your left side of the brain controls the right side of your body.” Similarly, Mr. M facilitated a discussion of the super notes among his students, asking: “What topic either strikes you as new information or something that you’d like to pick up as a thread and go deeper into?” Two students responded that they had learned something interesting about allergies, a topic they did not study in their home class. Students also reflected on how the super notes of Mr. B’s class related to their own work: “Me and J are doing the immune system… and we saw these notes about white blood cells, and that was really cool ‘cause white blood cells were part of your immune system. We don’t really know about them… it was really helpful for us…” Key ideas and questions picked up from the super notes of their partner classroom became the focus of deeper inquiry and dialogues.

**Discussion**

This study contributes a deeper view of student literacy practices that take place in elementary classrooms engaging in scientific sensemaking and knowledge building supported by digitally mediated environments. The findings identified five core features of reading, writing and interacting for knowledge generation. These features are characteristic of the new dimensions of literacy proposed by researchers such as dialogic and trans-literacy for authentic disciplinary inquiry (Bereiter & Scardamalia, 2005; Goldman et al., 2016; Liu, 2014; Thomas et al., 2007). As a key aspect of such literacy for knowledge generation, students work across multiple forms and sources of knowledge to make meaning and develop new understandings. Students may use a variety of sources such as books, websites, videos, and models to support their problem solving. Sometimes, when the resources are beyond their reading level, the teacher may provide help accessing them. While working with the information resources, students further generate personal ideas, questions, and narratives that build on their own life experiences and carry out experiments and investigations. What they think and encounter in each moment successively triggers deeper questions and new ideas, driving sustained cycles of sensemaking and idea improvement (Odden & Russ, 2019; Zhang & Sun, 2011).

Students engage in **dialogic literacy** as a social practice that supports dynamic networking of people and ideas in technology-augmented communication. Students participate in whole class discussions, form and work in interest-based groups, and continue their interactive discourse in an online environment. Ideas developed by some of the participants in any of these dialogic settings can be carried over to other dialogic settings that involve the same or different participants. Through the extended interaction, high-potential ideas may be further improved and diffused among the broader participants. Interrelated ideas may be combined and synthesized to develop coherent and complex ideas. New problems and challenges emerge from ongoing dialogues, informing directions of deeper inquiry.

Such literacy practices involve **boundary-crossing** between social groups and across different time periods. Ideas are continually developed on the basis of their intertextual past and further project into future contexts of inquiry and discourse. Specifically, students pay sustained attention (Liu, 2014) to ideas and information generated/encountered in various time-bound interactions, selectively revisit and build on the prior ideas as they pursue new/deeper inquiry. With the support of online environments that archive students’ knowledge artifacts, students have the chance to access and build on the knowledge generated by a network of classrooms, including previous student cohort groups who had studied the same (or related) topics. Generating knowledge artifacts that will be continually used by future students gives students an authentic purpose for productive inquiry and writing (Zhang et al., 2020).

We are conducting deeper analyses of the teachers’ role in scaffolding the key aspects of disciplinary literacy for knowledge generation. Future studies may design a reflective framework to guide teachers’ scaffolding of student literacy engagement in science inquiry. Analytics tools may be designed to help students monitor and improve their literacy practices as part of their knowledge building across disciplines.
References


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