

Making Collective Progress Visible for Sustained Knowledge Building

Mei-Hwa Chen, Jianwei Zhang, Jiyeon Lee
University at Albany

Email: mchen@albany.edu, jzhang1@albany.edu, edujyl@gmail.com

Abstract: This paper presents the design of Idea Thread Mapper (ITM), a timeline-based collective knowledge-mapping tool that interoperates with Knowledge Forum and potentially other learning platforms. Using ITM, students engage in collaborative, metacognitive conversations to identify “juicy” topics that have emerged from their knowledge-building discourse, as their communal focuses, and review ideas addressing each focus as a line of inquiry—an idea thread. A study was conducted in a grade 3 classroom to foster sustained knowledge building through ITM-aided collaborative reflection. Analyses of online discourse, classroom videos, ITM data, and student interviews elaborate the processes and benefits of ITM-aided reflection to foster student awareness of their collective knowledge and collaborative, sustained efforts to advance it.

Introduction

Schools need to cultivate collaborative, inquiry-based practices, by which knowledge-creating communities expand society’s knowledge. Knowledge productivity in such communities is achieved through a sustained trajectory of inquiry, by which ideas are continually generated, refined, and further built upon by peers to formulate more advanced ideas and problems. This process expands the community’s collective knowledge that continually informs further initiatives (Bereiter, 2002; Dunbar, 1997; Sawyer, 2007). However, current inquiry learning programs tend to focus on relatively short inquiry activities, carried out by fixed small-groups following tasks and procedures set up by the teacher. Further research needs to test designs that foster sustained, collective trajectories of inquiry in knowledge-building communities driven by student interactive discourse and ideas. To address this need, we created a timeline-based, collective knowledge mapping tool to make the collective trajectory of inquiry visible to students. Using this tool, students engage in reflective processes and conversations to co-monitor their collective knowledge and continually advance it.

Collaborative online environments have the potential to foster continual build-on and advancement of ideas (Scardamalia & Bereiter, 2006; Stahl et al., 2006). Integrating such online spaces into classroom interaction helps to give student ideas an extended public life beyond segmented activities, so the ideas can be continually revisited, improved, and taken up by community members as input to further cognitive operations (Zhang et al., 2010; cf. Dunbar, 1997). Knowledge that grows in this shared discourse space represents a product of the community as a whole—their community knowledge (Scardamalia & Bereiter, 2006) or group cognition (Stahl, 2006)—that leverages collaborative work and personal learning. Despite the above potential support, current online environments lack effective means to represent community knowledge in extended discourse, making it difficult for students to enact collective responsibility for monitoring and advancing it. In threaded discussions, chatting, and messaging, student ideas are distributed across individual postings over time (Suthers et al., 2008; Zhang, 2009). It is difficult for students to understand the conceptual landscape of their collective work, to identify knowledge advances, and to reflect on gaps and problems. Consequently, student online discourse is often disconnected, short-threaded, ill-grounded (Guzdial et al., 2001), lacks deepening moves, and focuses on addressing teacher-assigned questions (Zhang, 2009).

Therefore, fostering reflective awareness and monitoring of community knowledge has become a focal challenge (Engelmann et al., 2009; Suthers, 2001). The literature suggests a promising strategy that focuses on engaging students in creating synthetic knowledge representations during online discourse in forms of textual summaries or concept maps (Bell, 1997; Hewitt & Woodruff, 2010; Janssen et al., 2010; Suthers et al., 2008; van Aalst & Chan, 2007; Zhang, 2010). For example, in the work of Suthers and colleagues (2008), students created evidential maps to synthesize and review theories and evidence contributed to their argumentative discourse. These maps serve as collaborative “representation guidance” to foster reflective and coherent conversations (see also van der Pol et al., 2006). However, evidential/concept maps focus on small-group discussions of specific issues and may not be applicable to discourse of larger groups over an extended period, since they soon grow too large and complex to manage (Hewitt & Woodruff, 2010; Suthers et al., 2008).

New tools need to be created to represent collective knowledge progress in extended, online discourse. Such tools need to go beyond short discourse in small-groups to capture social and cognitive interactions over longer terms and at higher social levels within a whole classroom community and even beyond. Based on our previous research (Zhang et al., 2007), we created a timeline-based collective knowledge-mapping tool: Idea Threads Mapper (ITM). An idea thread represents a line of inquiry composed of a series of conceptually related

discourse entries that address a shared principal problem, extending from the first to the last discourse entry (Zhang et al., 2007). Interoperating with Knowledge Forum (Scardamalia & Bereiter, 2006), and potentially other collaborative learning platforms, ITM helps students to review shared focal themes of inquiry, as their communal focuses, that have emerged from interactive discourse, and identify important ideas contributed over time. This paper first describes the design of the ITM software and then presents a classroom-based study that uses ITM to support student collaborative reflection for sustained knowledge building.

Instrumentation: The Design of Idea Thread Mapper

The design of ITM is rooted in a view of knowledge-building discourse as multi-level, interactive, emergent systems (Zhang et al., 2009; Zhang, 2012). Through knowledge-building discourse, members in a community continually advance their collective knowledge: the state-of-the-art understanding of their community (Bereiter, 2002). Viewed from a complex systems perspective, community knowledge represents a community-level, macro structure that emerges from micro-level interactions focusing on diverse ideas contributed by members over time. Each idea, contributed by a member to the discourse, identifies certain things/issues to be investigated, as the focus and presents thoughts and work (a theory, question, experiment) to understand the focal issue. Peer members then respond to and build on the ideas to clarify and expand the focal issue to be investigated and examine and refine the concepts generated. Such interactions among the members give rise to the formulation of core and deep issues to be explored, as the community's focuses. Ideas contributed to address each major focus form into an unfolding line of inquiry, which often intersects with other lines of inquiry that investigate the related issues in the community's knowledge space. Online tools to represent collective knowledge thus need to capture and index the core focal issues to be investigated along with the concepts developed; both are progressively expanded and deepened as students engage in sustained knowledge-building discourse.

Working as a knowledge-building community, members engage in ongoing reflection to co-monitor how their diverse ideas relate, respond to, and build on one another to form unfolding conceptual streams and address important, focal goals. Additionally, they monitor how the different lines of inquiry evolve and relate to one another, advancing their collective knowledge. Such ongoing co-monitoring of ideas across the micro (individuals, small groups focusing on specific topics) and macro levels (the community as a whole unit, and beyond) will inform continual build-on and advancement of ideas across timescales. Students connect current inquiries to past inquiries and continually identify challenges and opportunities emerging from their current work to inform future inquiry.

ITM integrates three levels (or units) of ideas in knowledge-building discourse: an *idea* contributed in a discourse entry that conveys thoughts (question, conjecture) about a focal thing to be investigated, an *idea thread*, consisting of multiple discourse entries addressing a shared focus and its sub-focuses over a time period, and a *map/network of idea threads* for a whole inquiry initiative that may build on previous initiatives from the same or other communities. Constructing idea threads based on ideas contributed, synthesizing "Journeys of Thinking" in different idea threads, and mapping out a network of idea threads for whole-class reflection help students to see the larger picture of their collective knowledge space and, more importantly, it helps them rise above individual idea contributions to build coherent, high-level conceptualizations. Displaying idea threads on a timeline, with options to zoom in and out, helps students see idea build-on connections over time across multiple months (or years). A community can publish its idea threads and maps to share their progress of knowledge building with other classroom communities from around the world. Thus, metacognitive reflection and discourse supported by ITM enables multi-level, interactive and emergent knowledge building across the boundaries of time, discourse spaces, and communities.

ITM currently interoperates with Knowledge Forum, a collaborative online knowledge-building environment (Scardamalia & Bereiter, 2006). In Knowledge Forum, students contribute ideas, in the form of notes, to different views (workspaces) and build on one another's notes to engage in knowledge-building discourse. ITM was designed using a multi-tiered web architecture and implemented in JSP/Java programming language and MySQL database management system. A hierarchical view of ITM is shown in Figure 1.

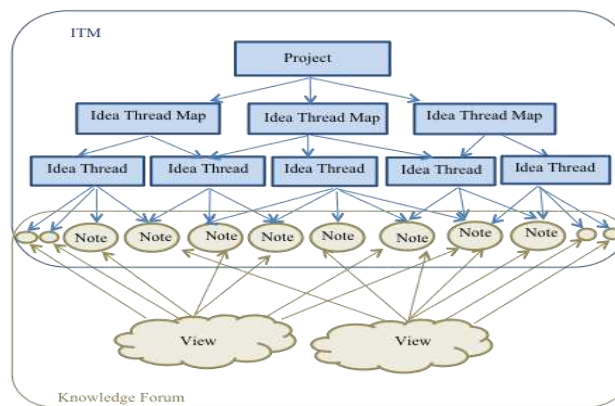


Figure 1. A hierarchical view of ITM.

ITM communicates with the servers of Knowledge Forum. On the basis of data (notes, views, users) retrieved from Knowledge Forum, ITM supports user actions to generate a map of idea threads for each inquiry initiative, as a project of inquiry. A teacher or student user can set up a project of inquiry by entering the topic of study, grade level, teacher's name, and school's name, and user groups involved. They then co-define communal focuses—core and deep issues to be investigated by their community in a domain area—and then search and select important Knowledge Forum notes for each focus to construct idea threads. A graphical chart is then displayed, rendering the distribution of the notes on a timeline from the first to the last note created (see Figure 2), with the options to zoom in to a specific time period (a day, a week) for a more detailed view. Each idea thread can be updated and edited by adding notes, removing notes, highlighting important notes, or renaming the focus of the thread. After reviewing the notes in an idea thread, students can summarize their “Journey of Thinking” in this line of inquiry, aided by a set of scaffold supports (e.g., *We want to understand*, *We used to think*, *we now understand*, *We need to read more about*). Such thread-based “Journeys of Thinking” (see Figure 3) are co-editable by all members of the classroom, with each version recorded for later review and analysis. To review collective progress in a whole inquiry project, the user can map out all the idea threads on the same timeline (see Figure 4) to examine idea progress and connection, identify productive advances, and decide on areas that need deeper work by the community.



Figure 2. An idea thread on how underwater plants grow created by a grade 3 classroom studying plants. There were 15 Knowledge Forum notes addressing this problem, from March 28 to April 16. Each square in the thread visual represents a note, and a line between two notes represents a build-on link. The lower part shows the list of note titles and the content of a selected note. The user can choose to show/hide titles, authors, and build-on links and zoom into a specific time period (by day, by week, by month).

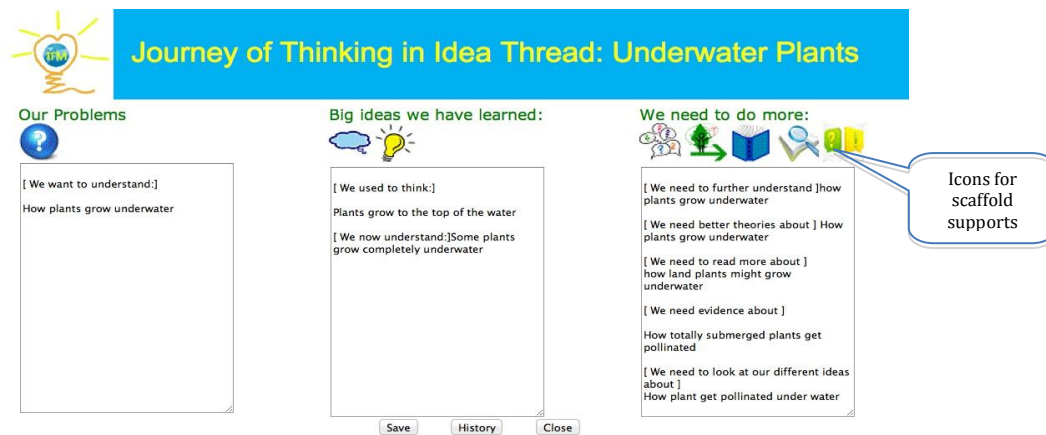


Figure 3. The “Journey of Thinking” summarized by a group of third-graders in an idea thread on underwater plants. It includes three sections: “Our problems,” “Big ideas we have learned,” and “We need to do more.” Texts in brackets (e.g., We want to understand) are scaffold supports added by clicking the corresponding icons.

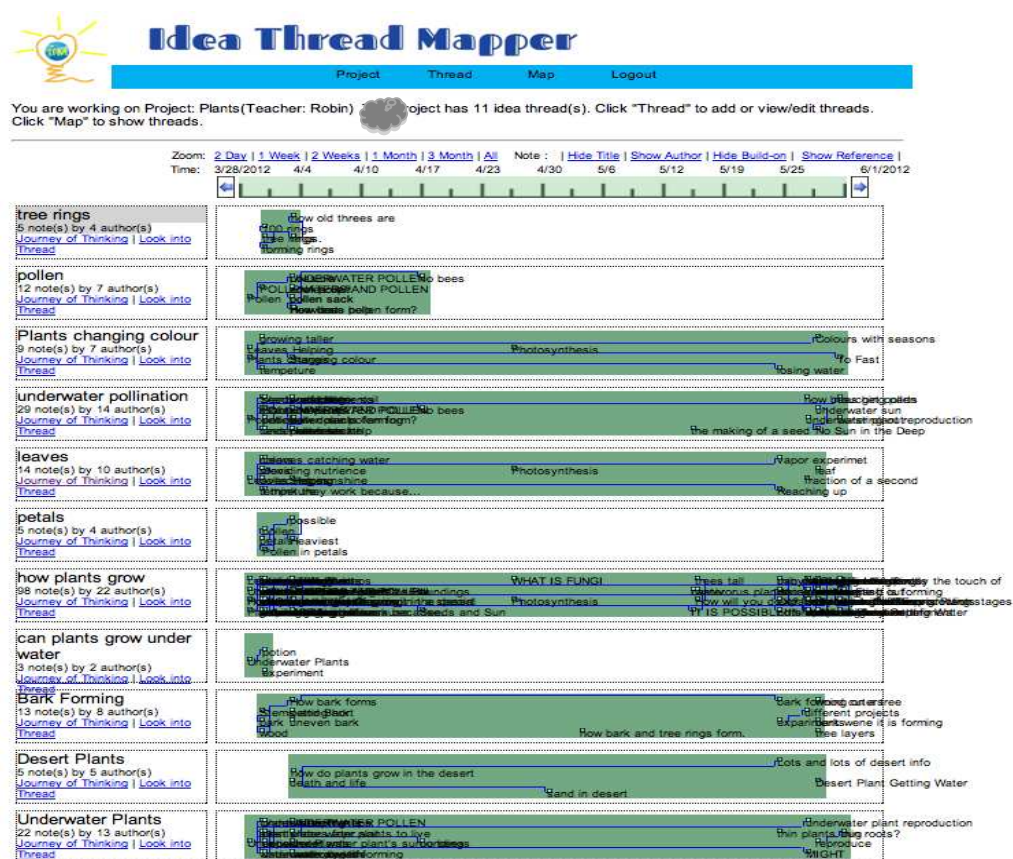


Figure 4. A map of idea threads created by a grade 3 classroom. Each stripe represents an idea thread. Each square in the threads represents a note, and a line between two notes represents a build-on link. Navigational links on the left allow the user to select an idea thread to view its details, make updates, create a “Journey of Thinking”

Classroom Research

To explore ITM-aided classroom designs to support collective, sustained knowledge building, a set of design-based studies was conducted in a grade 3 and two grade 5/6 classrooms (Zhang et al., 2013). The classroom designs focused on engaging student collaborative reflection on collective progress in their knowledge-building discourse. This paper presents our preliminary analysis of the grade 3 data. Our research question asks: In what

ways can young students benefit from ITM-aided collaborative reflection to better monitor their community's knowledge and make collaborative and sustained efforts to advance it?

Classroom Context

This design experiment was conducted in a grade 3 classroom with 22 students, taught by an experienced teacher. The students investigated plants over a two-month period. Their work integrated knowledge-building conversations, individual and group-based reading, student-designed experiments and observations, and online interactions in Knowledge Forum. Major ideas, questions, and findings generated in the classroom activities were contributed to Knowledge Forum for continual knowledge-building discourse. This design experiment involved two phases, marked by the first session of ITM-aided collaborative reflection around the middle of the unit. In the ITM session, which lasted about three lesson hours, students first worked in small-groups to identify “big ideas”—or “juicy” topics—from their knowledge-building discourse. The topics proposed were shared and discussed, resulting in a list of 11 topics. Focusing on one of the topics, underwater plants, the whole class used ITM to identify important Knowledge Forum notes and display the notes as an idea thread (see Figure 2). Temporary small-groups were then formed to construct idea threads for the rest of the topics and write a “Journey of Thinking” for each thread to reflect on the focal problems, progress of understanding, and deeper issues for further inquiry (Figure 3). The session concluded with a whole class conversation, with all the idea threads mapped out (Figure 4) and projected on a screen, to identify important knowledge advances as well as areas that required substantial deeper efforts. Focusing on the focal areas, deeper inquiry and discussions were conducted in the following month. The students then conducted another collaborative reflection session using ITM to revisit and update the idea threads. They reviewed Knowledge Forum notes created after the first ITM session, updated each idea thread to include selected important contributions, and further edited the “Journeys of Thinking” in reflection of their new insights and deeper questions.

Data Sources and Analysis

We video-recorded the ITM sessions to examine how the students engaged in collaborative reflection on their collective progress. The videos were transcribed and analyzed qualitatively to document the reflective processes. We interviewed five students before the first ITM session and five different students after the session, focusing on their awareness of themes explored by their community, knowledge advances and problems, and experience with ITM use. Complementing the video and interview data, we collected the notes taken by the small-groups that identified “juicy” topics of inquiry before the first ITM reflection. The interviews and notebooks were analyzed using content analysis (Chi, 1997) to categorize themes of knowledge advances and problems for deeper inquiry. Knowledge Forum recorded time-marked data about student online discourse, so we could analyze discourse patterns through social network analysis (Wasserman & Faust, 1994) and content analysis (Chi, 1997) to examine student collaborative deepening efforts.

Results

Student Awareness of Their Community's Knowledge

Prior to the first ITM reflection, five students were interviewed to identify important things they had investigated as a whole class. Each student identified 2.6 major themes on average (ranging from 1 to 5). The idea threads constructed by the whole class reviewed 11 themes as the community's focuses (see Figure 4), highlighting important lines of inquiry to the attention of all community members. As a student (JS) said in the interview: “it (ITM)... gives us a lot of information we didn't know.” Reviewing notes in different threads and co-summarizing the “Journeys of Thinking” further helped students to understand the focal problems and advances. As student NK commented: “you can see all the notes in different areas and then ... you can look into inside all the notes to see what people put in. Then it's really cool because you can see that, wow, these people put a lot into this.”

Collaborative Build-on of Ideas

As the video analysis reveals, the ITM reflection engaged students in metacognitive processes to co-construct “juicy” topics of inquiry in small-groups and as a whole class, search and review Knowledge Forum notes addressing each theme, select relevant and important notes to construct idea threads, and review all the idea threads to identify areas with major advances as well as weak areas for the community to further investigate. Doing so helped students realize how their own ideas connected to the contributions of their peers beyond those that they had explicitly built onto, to envision deeper challenges and goals for the community, and to formulate connected efforts. To gauge student collaborative efforts, we did social network analysis of the online discourse focusing on who had built on whose notes. The social network formed in the second half of the inquiry after the

first ITM session involved more intensive build-on ties, with the network density increasing from 9.74% in the first phase to 14.81% in the second phase.

Sustaining Idea Improvement

As the interview data suggest, ITM helped the students to see extended idea connection and progress through its temporal display of notes and build-on links, as well as its features to co-summarize the “Journey of Thinking” in each idea thread. When summarizing “Journeys of Thinking,” these young students could effectively identify problems of understanding as the focal goals and highlight conceptual advances achieved in their knowledge-building discourse. For example, reflecting on the development of understanding in the idea thread about petals, students wrote: “[we used to think] petals only make flowers look good. [Now we know] they help attract pollinators.” In the “Journey of Thinking” about underwater plants, it is said: “[We used to think] plants grow to the top of the water. [We now understand] some plants grow completely underwater.” In the “Journey of Thinking” regarding tree rings, students wrote “[We used to think] that tree rings help trees. [We now understand] that tree rings do not help trees but they do tell how old the tree is when you cut it down.” Focusing on the advances summarized, we traced and analyzed the notes in each idea thread and found that all the advances synthesized in the “Journeys of Thinking” were reflected in the actual Knowledge Forum discourse, often achieved through a series of discourse entries. At the end of the first ITM session, the community co-reviewed the map of idea threads to identify areas that involved productive discussions and advances as well as those that needed deeper inquiry (desert plants, underwater pollination, leaves, how plants grow in different conditions). In the last section in the “Journeys of Thinking,” students further proposed plans to investigate deeper questions in these idea threads using the scaffold supports provided by ITM. For example, the students wrote: “[We need to further understand] how plants grow.” “[We need to look at our different ideas about] how do the leaves help a plant grow.” “[We need to further understand] how underwater plants get pollinated?”

Focusing on the focal issues identified, students carried out intensive inquiry activities in the following month (May). These included problem-driven reading, experiments with underwater plants, a field trip to a wetland park, and extensive knowledge building conversations in the classroom and in Knowledge Forum. During the first week of June, the community conducted its second ITM reflection session to review new advances. Students identified 67 new notes that contributed to six idea threads, addressing issues related to how plants grow, underwater plants, desert plants, tree bark forming, leaves, and plants changing colors. As the build-on links in Figure 4 suggest, many of these new contributions in May built onto ideas contributed earlier, resulting in extended and sustained discourse. These new notes contributed more elaborate ideas than the notes created before the first ITM reflection, with the average note length increasing from 18.77 to 35.53 words per note.

For example, among the 11 idea threads, students carried out the most intensive discourse on how plants grow, a central topic that interconnects with other specific topics, such as leaves, pollen, and how plants grow underwater and in deserts. Students conducted reading, observation and dissection of plants, and rich discussions in the classroom and online. They developed initial ideas about how plants grow, as reflected in the following note:

Title: growing taller (by AF, 2012-03-30 09:43)

(My theory) the seed first attach the small roots into the ground then grows as it pushes out into the sky and drops the [actual] seed onto the ground. Then very tired it will eat the sunshine and store it into the leaves while the roots get the water and move it up the stem into the leave while the leave mixes it and turns it into food. Using the food the plant eats it and uses the energy of the food to grow taller.

Deepening their initial thoughts, students incorporated scientific concepts, such as photosynthesis, to refine their explanations. In the first ITM session, a total of 49 notes (1086 words) were selected by the students for the idea thread on how plants grow. Students further synthesized progress and identified deeper issues to be understood about how plants grow (e.g. how plants grow in different environments). The inquiry and discourse continued in this thread after the first ITM session, with the total number of notes increasing to 98 (2898 words) by the beginning of June when the second ITM session concluded. The contents of the new notes were found to be more focused and elaborated, with important progress explaining how different parts (leaves, pollen, seeds) of a plant help it grow in different environments (in deserts, underwater).

Title: underwater plant reproduction (by NK and AA, May 29 2012, 16:29:54)

Many plants are born from seeds that form after pollination, which can occur with the aid of the wind, with help from insects, and even in the water. When spring, many water plants cover themselves in flowers of striking [colors] and from each of [their] fruit more than 1,000 seeds may be freed (this is... from a book).

Title: Desert Plant Getting Water (by AD and MM, May 29 2012, 16:29:06)

A plant in the desert called [W]elwitschia mirabilis gets water from its massive leaves (2 meters.) The leaves will collect water from morning fog and channel it through the plant and into the ground where the water is collected by the plant's huge root. The reason that the water must go into the ground from the leaf is because it cannot process the other way by it coming through the plant's leaves.

Discussion

To support collective knowledge representation and progress in extended online discourse, we created ITM as a timeline-based collective knowledge-mapping tool to make the trajectory of inquiry visible for ongoing reflection and advancement. The classroom designs, enabled by the ITM tool, engaged students in collaborative, metacognitive conversations—metadiscourse—to identify “juicy” topics and ideas from their knowledge-building discourse, review contributions, synthesize progress, and plan for deeper inquiry. Students experienced multiple levels of “rise-above” to identify major focuses from their extended discourse, to share and consolidate these focuses into a collective list of deep and “juicy” themes as the community’s focal goals, and then to create reflective syntheses of conceptual advancement, based on incremental improvements made by different members over time in different lines of inquiry.

As the results suggest, such reflective processes helped to increase student awareness of their collective knowledge, including the focal issues to be investigated and idea development achieved by the community over the two-month period. Understanding and monitoring ideas across the community’s knowledge space becomes essential in knowledge-building classrooms that encourage diverse participation, distributed expertise (Brown et al., 1993) and student-driven deepening discourse, such as the classroom in this study. Through monitoring their collective knowledge space, students learn from knowledge advances of the whole community, beyond their personal focus, and build on important thoughts of others to advance the community’s understanding (Engle & Conant, 2002; Palincsar et al., 1993; Resnick & Hall, 2001; Roschelle & Teasley, 1995). After the first ITM reflection, the third-graders in this study engaged in more extended, focused, and elaborated dialogues to address the deeper problems that they had identified, resulting in a denser network of build-on connections and refined understanding of a diverse range of interrelated issues about how plants grow. Such collaborative, reflective, and deepening efforts, leveraged by the ITM tool, are essential to fostering a sustained, collective trajectory of inquiry in knowledge-building communities.

Building on the preliminary research results presented in this paper, we are conducting design experiments to test the impact of ITM-aided reflection on sustained knowledge building within each community and further develop designs to enable cross-community build-on of ideas mediated through student-created inquiry threads and summaries. The ITM tool will be upgraded to better visualize idea build-on within different idea threads and integrate automated analysis to help students identify idea thread focuses, select important contributions, and reflect on progress.

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