DEVELOPING A PRODUCTIVE KNOWLEDGE-BUILDING DISCOURSE THROUGH JUDGMENTS OF PROMISING IDEAS AND EPISTEMIC REFLECTION

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ABSTRACT

This study investigated whether elementary students could collectively advance a knowledge-building discourse through judgments of promisingness and epistemic reflection. Supported by the Promising Idea Tool and its accompanying pedagogical design, 32 grade six students were involved in judging the promisingness of their community ideas, refining ideas iteratively, and explicitly reflecting on their knowledge-building discourse using knowledge-building principles. We analyzed students' online discourse using multivariate methods, including socio-semantic network analysis and content analysis. Socio-semantic network analysis indicated that the students progressively advanced their community ideas and the community became more connected over time. Content-analysis results indicated that sixth graders could collectively improve their discourse by contributing diverse ideas, negotiating a fit, and generating questions, using problem-centered uptake moves and synthesis notes. The study's findings have important implications for the design of technology-rich environments, and shed light on how teachers can use them to help learners engage in productive collaborative inquiries.

KEYWORDS

Knowledge Building, Promising Ideas, Epistemic Reflection, Metacognition

1. INTRODUCTION

Helping students develop higher-order skills such as knowing how to inquire and collaborate, cultivate agency and metacognition, and create knowledge is an educational mission. Preparing students for collaborative, sustained and creative scientific practices that advance their higher-order competencies is therefore essential (Bransford et al., 1999; Zhang et al., 2018). Collaborative knowledge building, an influential pedagogical model in learning sciences, shows great potential for helping students develop these higher-order competencies.

Collaborative knowledge building, pioneered by Scardamalia and Bereiter (Scardamalia & Bereiter, 2014) emphasizes collective responsibility, improvable ideas, student agency and metacognition, and creative and promising ideas. In knowledge building, students' work is supported by Knowledge Forum, an online platform that facilities their knowledge building. The knowledge-building process is so emergent and complex that students, as active agents, need to continually identify promising ideas and evaluate the promisingness of ideas (Chen et al., 2015). To meet their emergent goals and invent new goals (Yang et al., 2016), they must reflect on the process, based on their assessments of the state of the learning process and its products (Zhang et al., 2018). The ability to judge the promisingness of community ideas and continuously reflect on the knowledge-building process to identify knowledge gaps and high points for further inquiry is critical to productive knowledge building. However, most Chinese elementary school students tend to receive teachers' instructions rather than participate as active players in learning. They generally lack the skills to judge the promisingness of ideas or engage in metacognitive reflection.

To address this challenge, this study designed a knowledge-building environment, augmented by judgments of promising ideas and epistemic reflection. To help students engage in productive judgments of promising ideas, students were provided with the Promising Ideas Tool, an analytic tool developed by Chen et al. (2015) and now embedded in Knowledge Forum. The Promising Ideas Tool can help students select

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promising ideas from their community's ideas and support collective decision making to identify promising directions for further inquiry (Chen et al., 2015; Chen, 2016).

The purpose of this study was to investigate whether sixth graders could collectively improve their knowledge-building discourse in a knowledge-building environment augmented by judgments of the promisingness of ideas and epistemic reflection. The study addressed the following research questions. (1) Did students' contributions and collaboration change during the knowledge-building process? (2) What was the nature of the knowledge-building discourse? (3) To what extent did students improve their discourse?

2. METHODS

2.1 Research Context and Participants

This study was conducted in an elementary school in Wuhan, China, with students mostly coming from middle- or upper-middle-class families. Thirty-two grade six (11-12 year old) students from one class participated in the study. The students studied the unit "shapes & structures" for eight weeks, with three 45-minute science lessons each week. They had no previous experience of knowledge building. The teacher was an expert in teaching science, with five-years of teaching experience. However, this was the first time the teacher had adopted a knowledge-building pedagogy.

2.2 Pedagogical Design

To help students engage in productive knowledge building, the teacher adopted the following components from the knowledge building pedagogical design proposed by van Aalst and Chan (2012):

Component 1: Creating a collaborative classroom culture and helping students develop competencies of inquiry-and-explanation and collaboration. To help students develop inquiry, explanation, and collaboration competencies, the teacher created several opportunities for student groups to engage in hands-on experiments, and for whole class discussions. For example, students in small groups collaborated to explore the effects of width and thickness on the resistance of materials to bending, built bridges using newspapers, and made towers using bottles and tubes (Figure 1). These activities helped them not only to learn to collaborate and communicate, but to develop the ability to inquire by asking questions, proposing hypotheses, designing and conducting experiments, and drawing conclusions through discussions and negotiations over the fit of diverse ideas. More important, these principle-based activities created a collaborative-inquiry ethos and norms for democratic participation.

Component 2: Advancing inquiry-oriented and idea-centered discussion through the Knowledge Forum discourse. The students shared their questions and ideas and discussed their initial experiments and findings in small groups and whole-class conversations. Focusing on the questions, the student groups conducted research with the help of books, experiments, online resources, and materials from their teacher. Extending their face-to-face knowledge building talks and interactions, the students recorded their questions, experimental findings, and ideas in Knowledge Forum to produce an ever-deepening online discourse (Figure 1). Knowledge Forum provided students with epistemic scaffolds such as "My idea," "My theory," "My evidence," "My conclusion," and "I need to understand" to help them develop the ability to inquire and explain.

Component 3: Deepening knowledge advances through judgments of promising ideas and explicit epistemic reflection. After the students had contributed a reasonable number of notes to Knowledge Forum, they were instructed to use the Promising Idea Tool. To help students engage in productive judgments of promising ideas, they were provided with metacognitive prompt sheets (e.g., including prompts like "My Analysis," "My Problem," "My Plan"). These helped them reflect on and monitor their discussions and plan the future direction of discussions. We also provided students with prompt sheets to help them synthesize their clusters of notes.

Figure 1. Knowledge Forum Views and Notes, and Hands-on Activities

3. DATA ANALYSIS AND RESULTS

The data sources for this study were primarily the computer notes the students posted on Knowledge Forum. The students contributed 247 notes in total.

3.1 Research Question 1

Research Question 1: *Did students' collaborations and contributions change during the knowledge-building process?*

To reveal the patterns of students' collaborations and contribution, we used a socio-semantic network analysis tool: Knowledge Building Discourse Explorer (KBDex, Oshima, Oshima, & Matsuzawa, 2012). KBDex was developed to analyze knowledge-building discourse, and it could support the metrics of the three different networks: degree centrality, betweenness centrality, and closeness centrality. Therefore, it could be used for visual inspections of semantic relationships, analyses of pivotal points and phases, and trend analysis. We selected 85 words from students' online discourse for analysis. The agreement between the two raters was 83%, and disagreements were resolved through discussion. We argued that the keywords could represent the discourse content, so the closeness of keywords' links and the quantity of keywords could represent the density and diversity of discourse content respectively.

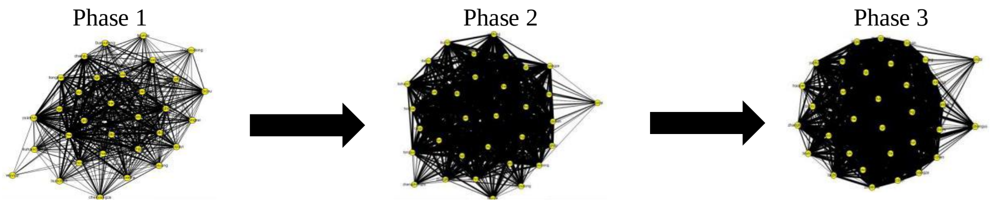

Figure 2 (a). Snapshots of the network of students over time

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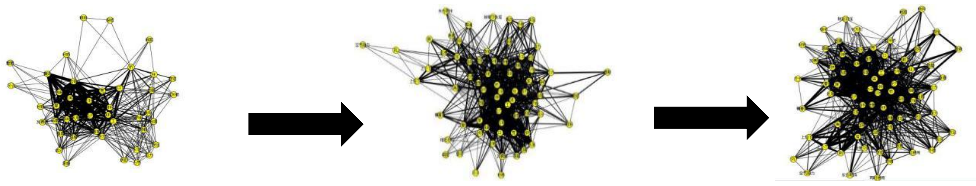

Figure 2 (b). Snapshots of the network of keywords over time

Figure 2. Snapshots of the network of students and keywords over time. Notes: The circle represented the student/keyword, and the connection between the two circles represented the relationship between them. The thickness of the line between the two circles represented the degree of correlation between them.

To investigate the changes of students' contributions and collaborations, we first identified two pivotal points to divide the knowledge-building process into three phases. Figure 2(a) shows that the density between the students increased from Phase 1 to Phase 3. Figure 2(b) shows that the keywords network structure was becoming denser, and extremely different keywords appeared from Phase 1 to Phase 3. These results suggested that the community was becoming interactive over time, and that students were engaged in productive knowledge building.

We further analyzed the patterns of contribution of students in the community through the changes to each student's sum degree coefficients in the three phrases (Figure 3). The gaps in the sum degree coefficients between students in Phase 1 indicated that their individual contributions were not democratic. However, the gap of the sum degree coefficients among individual students became smaller in Phase 3, indicating that they had progressively taken collective responsibility for advancing community knowledge.

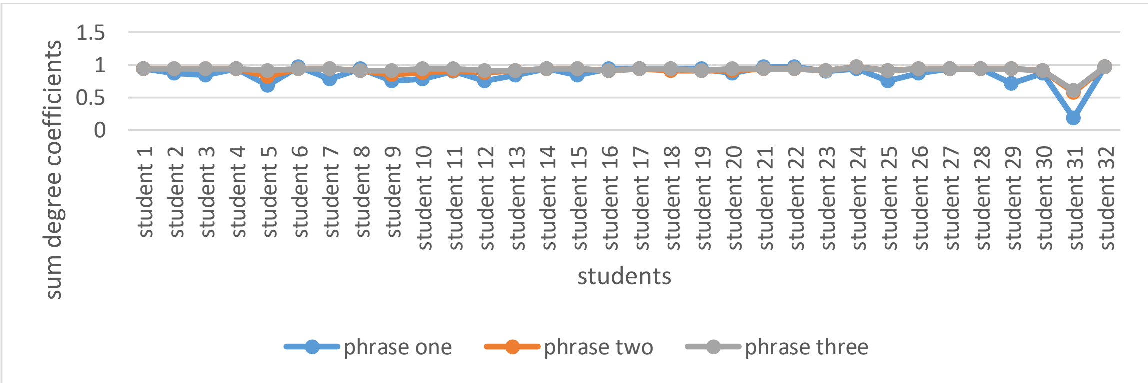

Figure 3. The changes of Sum Degree Coefficients of Individual Students in Three Phrases

3.2 Research Question 2

Research Question 2: What was the nature of the knowledge-building discourse?

To characterize the students' online knowledge-building discourse, we first pre-processed their notes into inquiry threads. This provided context for the subsequent content analysis of the notes within each inquiry thread. An inquiry thread was defined as a sequence of notes addressing a single problem (Zhang et al., 2007). Two hundred and forty-seven notes were put into 12 inquiry threads through inquiry thread analysis. To check the coding reliability of the inquiry thread analysis, two raters independently completed the task on 30% of the notes, resulting in an inter-rater reliability of .80 (Cohen's kappa).

After pre-processing the students' notes, we conducted content analysis using the inquiry thread as the unit of analysis. We developed a coding framework with coding examples to code the notes in each inquiry thread. The development of the coding framework involved an iterative coding process of theory- and data-driven approaches. The coding schemes (Table 1) included four main categories and corresponding subcategories, and drew upon theoretical frameworks for social, cognitive and meta-cognitive processes of knowledge construction (Authors, 2016; van Aalst, 2009). Two raters independently coded 30% of the notes. The inter-rater reliability was .78 for questions, .83 for scientificness of ideas, .78 for complexity of ideas, and .79 for community (Cohen's kappa).

We selected nine large inquiry threads and presented the numbers of questions, ideas and collective responsibility in them. The inquiry threads defined as large included more than 10 notes each. Table 2 shows that the elementary students in this class were engaged in explanation-oriented discourse: they focused more on explanatory than factual questions (24 compared with 7). They also generated more notes with elaborations than notes with simple claims (72 compared with 39). This result indicated that the students engaged in a deep rather than a superficial knowledge-building process.

Table 2 also shows that students invested a lot of effort in collectively advancing their community ideas. For example, they contributed many notes to negotiating a fit between diverse ideas (65 notes), showing idea uptake (41 notes), and rising above the community's ideas (17 notes). These results indicated that students in this class could take collective responsibility to improve their ideas progressively.

Overall, the above results suggested that elementary students in this class were able to assume high-level responsibility to collectively accomplish a knowledge-building discourse. They engaged in productive collaborations and gradually improved ideas in the communal space.

Table 1. Coding framework for content analysis of students' online discourse

Categories	**Subcategories**	**Definitions**	**Examples**
Question	Fact-seeking	Questions can be answered by factual information	*Please discuss those shapes such as ”一”,”W”, “口”,”工” which impacts the material most?*
	Explanation-seeking	Open-ended question that can only be answered by elaborative explanations	*Why shape "W" is the the most resistant to bending?*
Scientificness of ideas	Naive	Absolutely incorrect conceptions or theories, or naive ideas.	*The combination of arch, sphere, and frame structure don't have any drawbacks.*
	Hybrid	Ideas are basically wrong, but the understanding and explanation of the ideas are scientific under certain restrictions.	*I think shape "W" has a greater impact. Because shape "W" paper is wider so it's more durable than other shapes.*
	Basically scientific	The understanding and explanation of the concepts and theories in the discussion topics and issues are basically correct, but are not comprehensive and precise enough.	*I think the impact of shape "W" is even greater. Because "Thickness has a greater influence on the bending resistance of the beam." The thickness of shape "W" is thicker than other shapes. So the influence of shape "W" is greater.*
	Scientific	There is clear, scientific, and comprehensive understanding and elaboration of the concepts and theories of the discussion topics and issues, and the scientific theories contained in the discussion can be applied to practice.	*In response to the question "Shape W is not the thickest, why is the strongest resistance to bending?" One student responses that "because of the triangular structure, this is the most stable form".*
Epidemic complexity of ideas	Unelaborated facts	A description of terms/phenomena/experiences/simple judgments of a problem/idea without elaboration.	*Shape "M" has the strongest resistance to bending.*
	Elaborated facts	Elaboration of terms/phenomena/experiences in detail.	*The thickness has a greater influence on the resistance to bending of beams. Like the ruler we use, it is not easy to bend vertically.*
	Unelaborated explanations	Mention reasons, relationships, and mechanisms without elaboration.	*I have done experiments today. When the material is flat, the gravity coincides. When the material is folded, gravity is dispersed. So the resistance to bending is good in "U","T","O" and other shapes.*
	Elaborated explanations	Provide sufficient theories and evidences to elaborate reasons/ relationships/mechanisms.	*The shape of the tower plays a vital role. In our lives, we can see that the towers are generally small and light on the top while large and heavy on the bottom as a triangle. This is made to make the tower's chassis solid and firm, preventing the tower from falling. To make a triangle is because the tower is stable on the ground.*
Collective responsibility	Creating shared understanding	Creating elaboration or explanations of concepts or ideas to address the central problem; reformulating problems or focus.	*I think the resistance of bending of material is related to material, thickness and width.*
	Negotiating a fit	Constructing arguments or explanations in favor of; challenging the ideas brought in.	*Although there is a business certificate, if there is no application, the "W" beam is still useless. Only the "W" beam will be used on the construction.*

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			Therefore, there are various problems in the beam. The beam of "W" is not only difficult to do, but also unstable.
	Problem-centred idea uptake	Building up on peers' ideas to provide explanations in addressing the central problem and to deepen the inquiry including co-elaborating.	*I agree with your opinion. Because shape "W" is really difficult to do, and it is not easy to fix it on the ceiling. However, I have to add that the "W" shape of the beam is not beautiful, and the home will be a bit strange. But what shape can the beam make?*
	Synthesizing notes	Summarizing ideas from multiple notes by creating hyperlinks to a small number of notes relevant to it, extending the referenced ideas and introducing a new level of conceptualization.	*The arch can be placed at the bottom because it can withstand the weight of the dispersing force; the sphere can be placed on top because it cannot be placed underneath; the frame structure is played both in the building of the bridge and in the building of the tower. In summary, these three can be put together. The drawbacks are still there. The sphere does not play much role and can only play an aesthetic role if used improperly, because it will waste building materials.*

Table 2. Number of different categories of questions, epistemic complexity of ideas and collective responsibility in inquiry threads

			Question		**Epidemic complexity of ideas**				**Collective responsibility**			
	Students	Notes	Fact-seeking	Explanation - seeking	Unelaborated facts	Elaborated facts	Unelaborated explanations	Elaborated explanations	Creating shared understanding	Negotiating a fit	Problem-centred idea uptake	Synthesizing notes
Total notes (9 inquiry thread)	32	197	7	24	39	49	27	23	35	65	41	17
Mean	15.67	24.33	0.89	2.89	5.22	7.56	3.56	2.89	4.56	9.78	5.11	2.22
SD	4.92	9.81	2.00	1.61	5.04	5.34	2.13	2.61	5.00	3.93	3.18	1.30
#1	17	21	1	4	10	3	6	3	9	8	3	4
#2	13	20	6	2	17	8	2	4	15	10	11	2
#3	13	18	0	3	0	2	2	6	0	4	4	4
#4	26	42	0	4	2	4	1	1	1	6	3	1
#5	12	16	0	2	3	18	3	1	2	17	5	1
#7	11	20	0	3	1	9	6	6	1	14	6	2
#8	13	25	0	6	7	5	3	5	6	9	8	2
#9	21	40	1	1	6	12	1	3	6	12	2	3
#10	15	17	0	1	3	6	4	0	0	11	3	0

Notes: Inquiry threads defined as large included at least ten notes each. #1—Shape and its resistance to bending, #2—Beam and its resistance to bending, #3—The secret of arch bearing, #4—W shape and its resistance to bending, #5—Beam and W shape, #6—Overview of bridge and frame structure, #7—The structure of tower and stability, #8—Combination of arch, sphere and frame structure, #9—The placement of beam, #10—Column and W shape. Note: #6, #11 and #12 are not included because they were not large inquiry threads.

3.3 Research Question 3

Research Question 3: To what extent did the students improve their discourse?

To investigate the extent to which the students advanced their knowledge-building discourse, we first presented discourse advancement for each selected inquiry thread, followed by a demonstration of the characteristics of discourses before (Stage 1) and after (Stage 2) promisingness judgments and epistemic reflection.

3.3.1 Idea Improvement within Inquiry Threads

We rated students' personal ideas on a continuum from naive to scientific understanding, and from unelaborated facts to elaborated explanations, respectively, coding their personal ideas at different levels to distinguish the depth and epistemic complexity of them.

We first sequenced students' notes in the large inquiry threads based on the time of the last modification. Then we divided the notes into two stages (Stage 1 and 2, before and after judgments of promisingness and epistemic reflection). Finally, we compared the mean value of scientificness and the complexity of all ideas in the two stages. Table 3 shows that the scientificness and complexity of ideas improved from 2.95 to 3.25 and from 2.02 to 2.43, respectively. The results indicated that the students progressively generated ideas related to scientificness and they elaborated their ideas with increasing epistemic complexity.

3.3.2 Changes to Questioning, Ideation and Collective Knowledge Building

The characteristics of the students' knowledge-building discourse in the two stages were compared with the aggregated results for each stage (Table 3). Table 3 shows that there were differences between the two phases for questions, ideas and community knowledge. The students' notes in the later stage showed greater explanatory power, and focused much more on theory building (e.g., problem-centered idea uptake) and the review and 'rise-above' of ideas.

Table 3. Changes of Question, Idea and Collective Responsibility Over Time

		Stage 1		Stage 2	
Total notes		108		89	
		Frequency	Percentage	Frequency	Percentage
Question	Fact-seeking	8	7.41	0	0.00
	Explanation -seeking	15	13.89	9	10.11
Scientificness of ideas	Naive	2	1.85	0	0.00
	Hybrid	15	13.89	8	8.99
	Basically scientific	42	38.89	39	43.82
	Scientific	15	13.89	26	29.21
Epidemic complexity of ideas	Unelaborated facts	36	33.33	9	10.11
	Elaborated facts	25	23.15	40	44.94
	Unelaborated explanations	10	9.26	17	19.10
	Elaborated explanations	14	12.96	13	14.61
Collective knowledge building	Creating shared understanding	29	26.85	8	8.99
	Negotiating a fit	40	37.04	48	53.93
	Problem-centred idea uptake	20	18.52	23	25.84
	Synthesizing notes	9	8.33	9	10.11
Scientificness (Mean)		2.95		3.25	
Epidemic complexity (Mean)		2.02		2.43	

4. DISCSSION AND CONCLUSION

This study investigated whether sixth graders could collaboratively develop a knowledge-building discourse. We primarily analyzed the students' online discourse on Knowledge Forum, using multifaceted methods such as socio-semantic network analysis and content analysis. Socio-semantic network analysis suggested that students engaged in productive collaboration and made democratic contributions. They could advance their community's ideas collectively by generating explanatory-oriented discourse, negotiating a fit between diverse ideas, focusing on problem-centered idea uptake and synthesizing ideas.

This study has contributed to the literature in two ways. First, it showed that elementary students in an examination culture could identify and evaluate promising ideas and carry out metacognitive reflection. These skills are critical for productive knowledge building, and can help students develop agency and self-direction in their ongoing knowledge building work within a supportive learning environment. In prior research, many teachers and scholars have expressed doubt that Chinese elementary students could do such higher-order work (van Aalst & Chan, 2007). Second, the pedagogical design (including the three components of collaborative ethos, staging principle-based tasks for collaboration and reflection, and promisingness judgments supported by the Promising Idea Tool in the community context) was conducive to elementary-school students. Thus, it could have important implications for the design of technology-rich environments to support learners.

This study had some limitations. One important limitation was that the study focused on discourse, and did not investigate changes in the domain knowledge of individual students. The findings provided evidence of idea improvement within the discourse, but it is unclear how widespread these changes were among the participants, or whether the changes were *transferable*. Another limitation was that we did not include or analyze classroom data sources such as classroom videos and observations. Nonetheless, such data is critical for a better understanding of students' online knowledge-building discourse and what contributes to their productive knowledge building. We are now conducting an analysis of classroom data sources to understand classroom processes and dynamics conducive to productive knowledge building.

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