Principle-Based Design for Collective Growth: from Knowledge-Sharing to Explanatory Knowledge-Building Discourse

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Abstract: This study reports on classroom studies of knowledge building, supported with Knowledge Forum, conducted over two years with two teachers new to knowledge building and their Grade 4 students. This study examines how the two teachers engaged in increasingly sophisticated classroom design over time, and how their students moved towards more collective work and productive discourse. Obstacles and opportunities were identified as the researcher worked with the teachers to emphasize principle-based and collective design. Analyses indicated that, over time, students participated more in Knowledge Forum in terms of community awareness and connectedness, and moved more from knowledge-sharing to explanatory knowledge-building discourse. Analyses of students' posttest scores on science tests indicated that students' Knowledge Forum participation was positively correlated with domain understanding. Examining new teachers' shifts in classroom designs and their students' changes towards explanatory discourse may have implications for identifying the developmental trajectories of knowledge-building dynamics and practice.

Introduction

Helping students to engage in knowledge building is an important research theme in computer-supported collaborative learning and learning sciences. One particular model of knowledge building, also called knowledge creation, focuses on the creation and improvement of ideas and public knowledge in communities. When ideas are placed in the public, knowledge itself becomes an object of inquiry, and the community works collectively to make collective advances (Bereiter, 2002; Scardamalia & Bereiter, 2006). Knowledge Forum (KF), a computer-supported collaborative learning environment, is a knowledge-creation space that enables students to make their ideas public for progressive discourse and theory revision.

Over the last 20 years, major theoretical advances have been made with theory, pedagogy and technology of knowledge building (see special issue, Scardamalia, 2010). Research has shown that even young children are capable of engaging in collective cognitive responsibility to create new knowledge (Zhang, Scardamalia, Reeve & Messina, 2009). The knowledge building model has now been implemented by school systems in many countries, and there is an increasing need to understand the dynamics of knowledge building and how it can be implemented in a range of classrooms. Whereas attention has been given to how more experienced knowledge-building teachers engage in classroom design (Caswell & Bielaczyc, 2002), less is known about students' knowledge-building trajectories and knowledge-building practice among novice teachers. The goal of this study is to characterize knowledge-building discourse, in order to identify developmental trajectories and to explore the designs that facilitate teachers to make these changes. Specifically, this study examines teacher and student growth trajectories by following, over the course of two years, two Hong Kong teachers who teach the same curriculum topics and are both new to knowledge building.

Developmental Patterns of Knowledge-Building Dynamics and Discourse

Since the 1990s, considerable research has been conducted for characterizing knowledge-building processes and dynamics. Different patterns of knowledge building dynamics have been identified, for example, referent-based versus problem-centered knowledge (Oshima, Scardamalia & Bereiter, 1996); fact-based versus explanatory-based inquiry (Hakkarainen, 2003); and depth of questions and explanations (Lee, Chan & van Aalst, 2006) More recently, van Aalst (2009) has identified three kinds of knowledge building discourse – knowledge sharing, knowledge construction, and knowledge creation – associated with the emergence of new knowledge and social dynamics. Such kinds of analyses, rather than merely coding and counting CSCL discourse categories, imply increasingly sophisticated patterns of processes and dynamics in knowledge-building discourse. The question is, can these patterns of discourse be identified to characterize developmental trajectories of productive knowledge building?

Analyzing knowledge-building dynamics and trajectories is useful, not only for characterizing the nature of knowledge building, but also for examining changes in teacher and student knowledge building practices. Hakkarainen (2003) report on changing from fact-based to explanatory-based inquiry over a three year period; and Zhang *et al*'s (2009) three-year design-study into changing fixed, interactive group dynamics to opportunistic group dynamics with increased community awareness and community connectedness, for example – have specifically examined changes over time. These patterns may suggest pointers for identifying and developing more sophisticated processes and practices. Nevertheless, most of these studies have involved

comparatively sophisticated teachers, rather than investigating knowledge-building dynamics trajectories by examining novice teachers' growth towards adopting knowledge-building innovation and tracking changes in their students' discourse. The scheme of knowledge-building discourse (van Aalst, 2009) was identified among Canadian high-school students; it would be useful to examine further possible developmental patterns and to investigate whether and how elementary school children change from knowledge-sharing to knowledge-construction and to knowledge-creation discourse.

From Activity-Based to Principle-Based Design

Questions also exist as to how new teachers can adopt more sophisticated knowledge-building practice to facilitate more productive knowledge-building discourse. A major challenge for teachers working on inquiry-based and knowledge creation model is to shift from tasks and activities to principle-based understanding for classroom innovation. The traditional classroom model is one of highly-structured initiate-response-evaluation (IRE) patterns, with a focus on individuals, so how can teachers move towards designs for collective cognitive responsibility? Scardamalia and Bereiter (2006) contrast principle- and procedural-based approaches: A key idea in principle-based innovation is that teachers need to go beyond activities and view principles as objects of inquiry; knowledge-building principles can point to and scaffold collective designs(Scardamalia, 2002). There is some evidence that principle-based understanding sustains teacher growth in school innovation (Zhang, Hong, Scardamalia, Reeve, & Messina, in press). Research has also shown that teachers in a knowledge-building network vary in how they emphasize principles versus activities, and that the students of those inclined towards principle-based understanding have more sophisticated views of collaboration (Chan, in press). Accordingly, this study examines the idea that as new teachers move towards principle-based collective designs, they are better able to bring about changes in their students' productive discourse.

To summarize, the research objectives for this study are to: (1) examine teachers' classroom designs and to investigate how they change from activity- towards principle-based designs over a two year period; (2) investigate how teacher change in classroom designs parallel their students' change towards increased community connectedness and explanatory knowledge-building discourse; and (3) examine whether student engagement in knowledge building activity is related to their domain understanding.

Methods and Design

Participants

The participants were two elementary-school teachers (hereafter called TC and TT) and their Grade 4 students, who were examined over two school years (2008-09 and 2009-2010). TC and TT had 9 and 5 years of experience respectively, when they joined the project. Both taught in a public school located in a low income area of Hong Kong with children of low-average academic levels. In Year 1, TC's and TT's classes had 40 and 33 students respectively; in Year 2, the numbers were 39 and 29. The two teachers implemented the knowledge-building approach in both semesters of both years; the selected topics were "Plants" and "Human Body". This design made it possible to track how these new teachers made change and as reflected in their student participation. To control for differences in student background and improvement due to a strong cohort, school information was collected. Students in Year 1 and Year 2 were similar in terms of School Attainment Test scores (similar to standardized test scores), with Year 2 students in both classes being generally weaker.

Designing and Implementing Knowledge Building

Year One Implementation – Initial Work

While the two teachers both subscribed to student-centered learning, both emphasized steps and procedures: At the start, they listed their strategies: Students would (a) read materials in library; (b) watch documentary films to stimulate interest; (c) ask 'wh' questions about the topic; (d) select the three most popular questions for KF work; (e) learn KF functions; (f) participate in student discussions using KF; and (g) produce concept maps and a learning diary. TC began with implementation – he was concerned that he could not deal with students raising too many questions, thus only three questions were chosen for KF discussion. Figure 1a shows an interesting pattern that is characteristic of teachers and students new to knowledge building – although many notes were made, most were short and fragmented, and formed a kind of 'spider-web' pattern around the centralized node as students wrote responses to the parent question.

Ongoing evaluation indicated that, while students were relatively engaged and that many notes were posted, the responses were superficial and repetitive. We worked with the two teachers to identify areas needing refinement. Fig 1a shows that students viewed discourse as a question-answer pattern, analogous to the teacher asking a question that had to be answered. Moreover, they did not see that the discourse is intended to build on and extend others' ideas for community advances, and kept giving the same responses, mostly short answers with no explanation. Students typically just answered the question or clicked on a random note. TT and

TC worked with each other - While TT also used three questions and responses were still fragmented and descriptive, the spider-web pattern seen in TC's class did not exist in his. TT and TC were sufficiently impressed with what their low-achieving students could do using KF, that they continued the project with the next semester's topic, the Human Body. After an initial phase of question-answer responses, students became more engaged in posing questions and building on each others' responses. Discourse was still superficial but improving to more divergent pattern (Fig 1b) -- students tended to ask questions about difficult terminology (what is X or Y?) without linking them to the problem at hand.

Year Two Implementation – Towards Principle-Based Design

Throughout Years 1 and 2, TT and TC worked with the researchers and other peer teachers in the context of a knowledge-building teacher network (Chan, in press). Teachers were encouraged to view classroom design problems as objects of inquiry and they also employed technology in ways that are connected with the principles. Focus was placed on principle-based design emphasizing individual to collectivist stances. As TT and TC worked on the same topics with parallel classes, they helped scaffold each others' advances. The change process was gradual and emergent; classroom designs of Year 2 informed with principles are described:

Epistemic agency. TC and TT no longer restricted the number of questions posed by their students, and became more comfortable letting students ask the questions they needed to have answered. TT noted that students would give deeper responses when they felt they were asking questions to which they genuinely wanted answers. While their goal is to help students develop collective agency, it was not an exercise in discovery learning; they worked with their students to connect their wonderment with big ideas in the domain.

Community knowledge. The teachers addressed the problem of repetition by using the analogy that people in a conversation do not keep repeating what others have already said; rather, they listen to what has been going on and move forward the conversation. The teachers helped students to change gradually from the predominant question-answer patterns to ones that involve interaction, contribution, and discourse -- A divergent and distributed pattern now emerged. While TT and TC had asked students to work in groups in Year 1, later they created an overall view and used rise-above notes to develop community knowledge (Figure 1c).

Improvable Ideas. To help students move past shallow knowledge-sharing, a major change was introduced in Year 2 – the use of "knowledge-building talks" in which students' emerging questions were reflected upon. TC worked with students on what he called 'cutting-edge' recommended notes. In the past, some important ideas might have gotten lost; and students shied away from difficult questions; now the teachers encouraged students to help each others to improve their ideas.

Constructive use of information. TC and TT provided their students with relevant information to encourage them to move beyond chit-chatting and sharing opinion. Both teachers were working on the problem in that some students simply copied the information from the web into their KF notes without interpretation.

Embedded assessment. While the teachers were concerned with assessment, in Y1, they asked students to reflect on their understanding using concept map in paper and pencil. Over time in Year 2, both teachers were better able to use collective assessment with reference notes on Knowledge Forum..

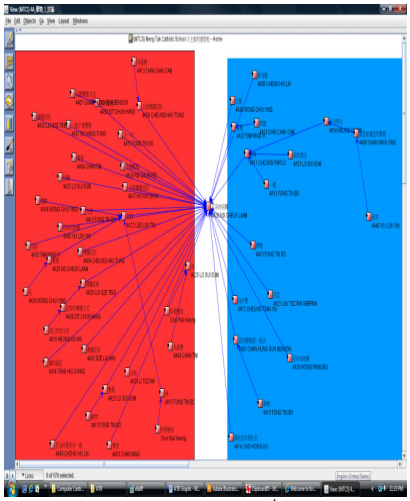


Figure 1a. KF View in 1st Yr TC.

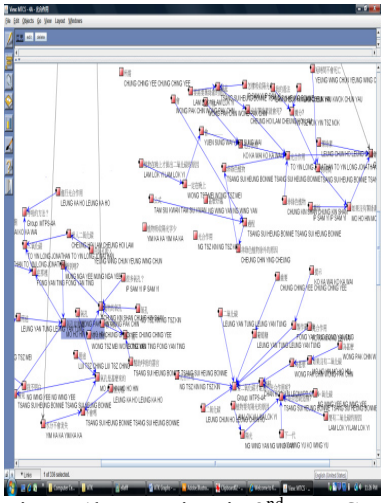


Figure 1b. KF View in 2nd Yr TC.

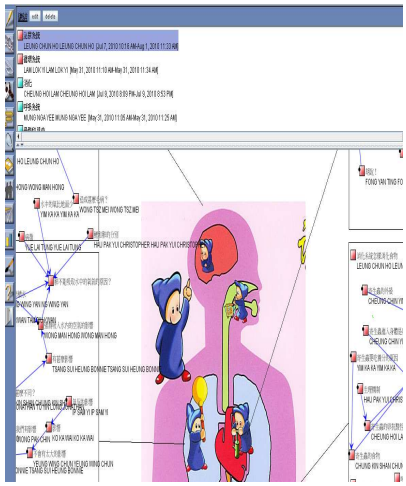


Figure 1c. KF View in 2nd Yr TC.

Results

Changes in Students' Knowledge Forum Participation over Two Years

Community Awareness and Connectedness (Applets –Note-Reading and Build-On Density)

Data were collected to examine whether the two teachers had changed over time, based on their students' participation and collaboration patterns on Knowledge Forum. The mean number of notes written were 8.7 to 16.7 for TC and 4.5 to 19.5 for TT' classes in Yr 1 and 2. We employed two Knowledge Forum assessment Applet indices – "Note-Reading Density" and "Build-on Density" to gauge student progress in the knowledge building community; the indices are similar to Social Network Analyses, but simpler to use. Density is calculated as the ratio between the actual number of links and the maximum possible number of links. Zhang et al. (in press) note that the extent to which students read others' notes reflects "community awareness" and that building on reflects "community connectedness"; both are used here to indicate whether students are moving towards more community cohesion. There were changes in Read-Density (TC: 84.5%--100%; TT: 79.3%—93.65%) and Build-on Density (TC: 29.2% –32.7%; TT 18.6%--43.9%) over the two year period. Figures 2 and 3 show the changing patterns using Applet visualization patterns for build-on notes. These results indicate that students of both teachers had more connected interactions on KF participation comparing Year 1 and Year 2.

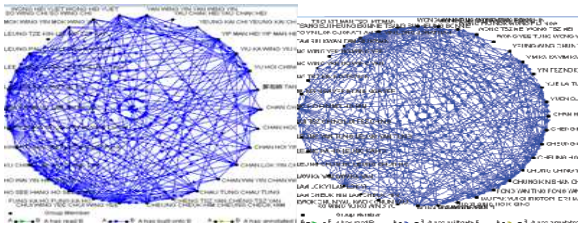


Figure 2. Note-Build-on Density in Years 1 and 2 (TC).

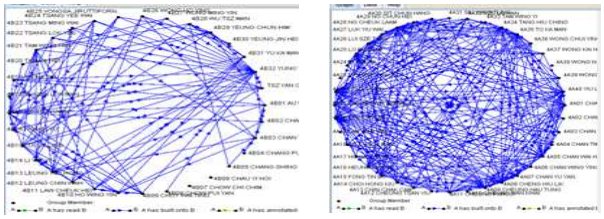
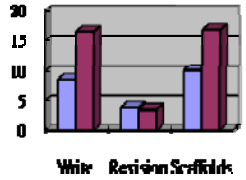


Figure 3. Note-Build-on Density in Year 1 and 2 (TT).

Participation and Collaboration (Analytic Toolkit Indices)

Student participation on KF was obtained using server log information via Analytic Toolkit, a software with Knowledge Forum.. Several indices used in previous studies were generated including "write", "revision", "scaffolds", "keywords", "read", and "link" (Lee et al., 2006). Figs 4 & 5 show changes in student participation over the two years for the ATK indices. To provide a more coherent analysis, the ATK participation indices were factor analyzed, and two factors were obtained called "Productivity" (write, read, revise, scaffolds) and "Collaboration" (linked, keywords), consistent with findings in other studies (Lee et al., 2006). Statistical analysis indicates marginally significant differences between Years 1 and 2 for ATK Productivity, F =3.34, p <.08; and significant differences for ATK Collaboration, F = 4.17, p <.05 with higher ATK scores in Year 2. When the two classes were examined separately, there were differences for TT's class but not TC's classes. Taken together, these two sets of quantitative indices (Applets + ATK) suggest that there was more participation, collaboration and connectedness among student cohorts for the teachers over the two years.



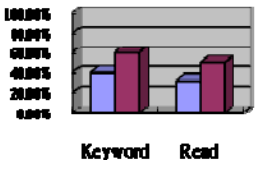
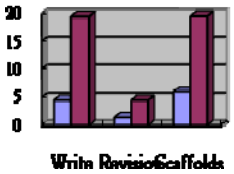


Figure 4. ATK Forum Participation Indices (TC).



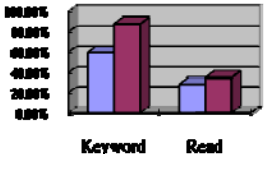


Figure 5. ATK Forum Participation Indices (TT).

Changes in Discourse Over Two Year

Characterizing and Analyzing Knowledge-Building Discourse

Students' forum writing was analyzed for discourse quality by adapting Zhang et al' notion of conceptual threads (2007) grouping forum notes into different discussion/inquiry threads. These discourse threads rather than individual notes or adjacent pairs were the unit of analysis for tracking changes in knowledge quality. Discussion threads were then coded into four levels using the idea of different types of knowledge-building discourse (van Aalst, 2009):

- *Fragmented discussion.* Short discussion threads with fragmented responses; an example is the pattern of short answers and questions as described in Figure 1.
- *Knowledge-sharing discourse.* There are two types: short threads in which a student asks a question and someone responds often using information copied off of the internet. The second involves conversational interaction in which opinions or information is shared without supporting evidence or explanation. Table 1 shows an example in which a student asks what might happen if a person had only one lung. Several

students respond with either opinions or general ideas (#3-6). There was interaction but no attempt to formulate the problem to understand the respiratory system. The discourse then degenerates into conversations about lung disease and that thinner people are weaker and more susceptible to lung diseases (#11-12). Although students are interacting, they are primarily exchanging opinions.

Table 1: An example of a knowledge-sharing thread.

Student	Discourse Moves	Excerpts from the inquiry thread
1. HSH	Asks a question	I need to understand We have a pair of lungs. If we only have one side of the lung, can we still breathe? Why?
2. CCY	shares opinion	My theory If we only have one side of the lung, we can still breathe, because the only reason for us to have a pair of lungs is to breathe smoothly. If we only have one side of the lung, we cannot breathe smoothly.
3. LYH	shares opinion	My theory Lung helps us to breathe. We can breathe with one side of the lung. We will certainly die, if we do not have a pair of lungs.
4. CT	shares opinion	My theory I guess we cannot breathe with one side of the lung.
5. CWY	shares opinion	My theory Can breathe.
6. YMH	shares opinion	My theory Yes, but it would be much harder. The job to breathe should be done by a pair of lungs, but now it is done by one side of the lung only.
7. WHY	share opinion	My theory One side of the lung is also a respiratory system, though breathing is pretty hard.
8. CWY	Asks a question	I need to understand why do we not die with one side of the lung?
9. LYK	digression	I need to understand What will happen if there is a hole in the lungs?
10. CCY	shares opinion	My theory It is called burst lungs. It makes breathing very difficult. It usually happens in people who are thin and tall.
11. CWY	Asks a question	I need to understand Why people who are thin and tall often have burst lungs?
12. YHC	shares opinion	My theory Because those thin and tall people are weak.

Notes: Students wrote in Chinese on KF; these excerpts are translated for illustration. Many discussion threads are long, and only selected notes are included here to highlight the key features.

- *Knowledge-construction discourse*. Attempts were made by students to construct understanding using questions and explanations. Table 2 shows an example in which a student asks why plants release carbon dioxide at night (#1). Another student responds that plants release carbon dioxide and absorb oxygen at night and the other way round in the morning, which leads to a discussion of the role of CO2 in photosynthesis (#3-5). There are good efforts to build on others' ideas with questions and explanation.

Table 2: An example of a knowledge-construction thread.

Student	Discourse Moves	Excerpts from the inquiry thread
1.WTM	asks a question	I need to understand Must plants release carbon dioxide in the evening? Why?
2.LLY	elaborates and includes information	My theory Plants must release carbon dioxide at night because, in the morning, plants absorb carbon dioxide and release oxygen. In the evening, plants absorb oxygen and release carbon dioxide.
3.MT	asks a question	I need to understand Why do plants need carbon dioxide to have photosynthesis?
4.CHJ	explanation	My theory Because carbon dioxide is a raw material for nutrition production…
5. LLY	Uptake; elaborates & explains	My theory Plants need carbon dioxide to have photosynthesis because some procedures of photosynthesis require the combination of the carbon dioxide and glucose for oxygen…
6.KWY	explanation	My theory If there is no carbon dioxide, plants cannot have photosynthesis to produce nutrition. Plants will die and not have reproduction.

- *Emerging knowledge-creation discourse.* Table 3 shows an example with sophisticated explanatory and emergent discourse. The thread begins with a question about how non-green plants produce food, as they may not have chlorophyll. The initial response is a misconception, but allows others to seek clarification

and leads to revision for better understanding. One student deepens the inquiry, asking how red leaves can have photosynthesis (#5), to which another student discusses how to test the theory that red leaves can make food through a laboratory experiment (#6). These responses, from Grade 4 children, reflect sophisticated discourse -- puzzlement are raised that spawn questions; theory testing through experiments and theory building using new information and explanation (#7-8) This emerging knowledge creation thread is characterized by question-explanation, emerging questions and theory testing.

Table 3: An example of an emerging knowledge-creation thread.

Student	Discourse Moves	Excerpts from the KF note
1. MT	asks a question	I need to understand How do non-green plants produce chlorophyll and nutrition?
2. YLT	poses idea thus misconception can be inquired further	My theory Non-green plants cannot have photosynthesis; therefore, they are parasite on plants that have chlorophyll. They absorb nutrition from other plants.
3. TSH	indicates puzzlement & asks for explanation	I need to understand How can non-green plants be parasite on green plants, and how can they absorb nutrition from other plants? (What is the process of such absorption?)
4. LLY	Provides explanation	My theory In fact, similar to green-plants, non-green plants contain chlorophyll. Non-green plants do not need to produce chlorophyll, and they produce nutrition the same way as other plants.
5. KCY	asks a question	I need to understand How do red leaves have photosynthesis? Why?
6. MHH	hypothesizes and proposes an experiment	My theory Red leaves also have chlorophyll, even though such chlorophyll is red in color instead of green in color. We can conduct the same experiment shown in the textbook… Put red leaves in a test tube, and then pour iodine on the leave… We can test whether the red leaf can have photosynthesis or not?
7.KCY	Clarifying question	I need to understand Is it call "red" chlorophyll?
8. LKH	Uses new information to construct explanation; deepening inquiry (my theory--new information--my theory)	My theory … the major pigment in chlorophyll is green in color. When plants have a lot of chlorophyll, they are green plants. New Information …For example, red algae contain "algae bile pigment"; brown algae contain a "black algae yellow substance."… My theory Those color [crowd out] the green color in chlorophyll. That is why we see non-green plants. The non-green plants use those … colors to absorb the light and move the energy to chlorophyll? Such other colors are indirectly involved in the process of photosynthesis…

Note: The Chinese translation of chlorophyll includes the word 'green', thus students were puzzled about whether non-green plants have chlorophyll and how they can make food.

Changes in Quality of Discourse and More Sustained Inquiry

Student discourse in both years and with both teachers was grouped into discussion threads and coded into the four levels (Table 4) indicating an improvement in discourse patterns. Specifically, the number show that knowledge-sharing patterns decreased over time, while knowledge-construction threads and emergent knowledge-creation threads increased. Ongoing analyses were conducted to establish inter-rater reliability for the coding of these threads. Since knowledge building involves sustained inquiry, to provide a fuller picture, the threads were plotted to illustrate the extent to which students were continuing with their inquiry over time versus short threads for question-answer. Figures 6 and 7 show the discourse threads for the topic 'plants' for TT and TC (Yr 1 & 2). The plots of the discussion threads indicate some distinctive differences – Comparing Years 1 and 2, students wrote more threads, and these threads lasted for more days suggesting that students of these teachers were more engaged and sustained in their knowledge-building inquiry.

Relations between Participation on Knowledge Forum and Domain Understanding

The third research question examines whether student engagement with knowledge building measured by their participation on Knowledge Forum is related to their domain understanding, We collected data from (a) a domain test that consists of two questions (what have you learned? what would you like to find out?) and (b) examination scores in general science as students' regular assessment practice in schools. We followed the approach employed in other studies (Lee et al., 2006) and coded student responses using a 5-point scale ranging from fragmented to scientific responses. The four scores from the two units (Plants and Human Body) were combined, yielding mean domain test scores of 2.5 (TC) and 2.8 (TT). Analyses were conducted to examine if

student participation on Knowledge Forum, as measured by ATK indices, was related to domain understanding. As mentioned above, factor analyses of the indices generated two factors – ATK "Productivity" and ATK "Collaboration". Correlation analyses indicated that students' domain test scores were correlated with ATK Collaboration (r = .26, , p <. 04); and school exam scores were correlated with ATK Productivity (r = .28, p <.03). Separate analyses showed stronger patterns in TC's class. Overall in both classes, students' participation indices on Knowledge Forum were significantly related to their domain understanding.

Table 4: Changes in discourse patterns for student cohorts in two years.

	TC (4A)				TT (4B)			
	2008-09		2009-10		2008-09		2009-10	
	No.	%	No.	%	No.	%	No.	%
Fragmented	1	4.2	1	2.78	7	50	0	0
Knowledge Sharing	20	83.3	25	69.4	5	35.7	23	69.7
Knowledge Construction	3	12.5	6	16.7	1	7.1	7	21.2
Emerging Knowledge Creation	0	0	4	11.1	1	7.1	10	9.09
Total	24	100	36	100	14	100	33	100

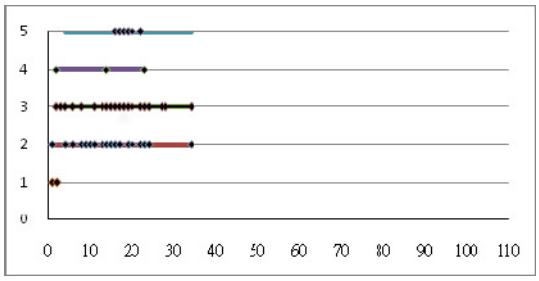


Figure 6a. Short Discourse Threads (Year 1 TC).

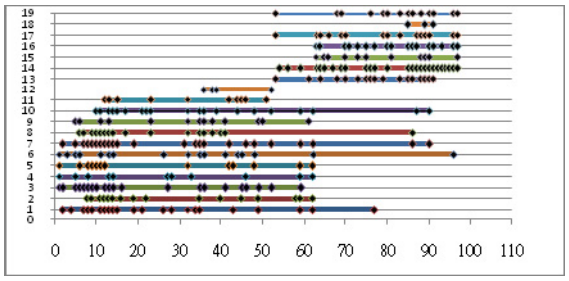


Figure 6b. Sustained Discourse Threads (Year 2 TC).

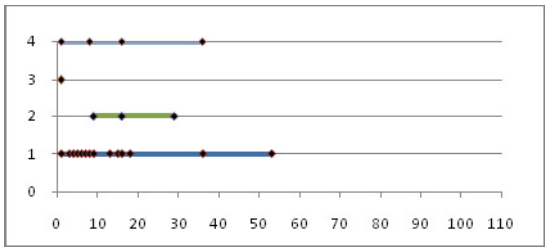


Figure 7a. Short Discourse Threads (Year 1 TT).

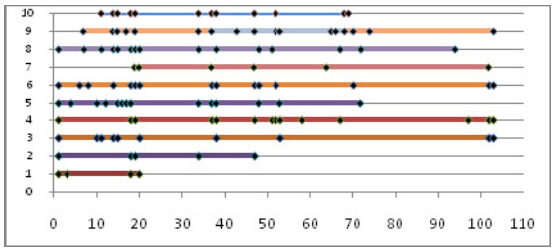


Figure 7b. Sustained Discourse Threads (Year 2 TT).

Discussion

Despite the enthusiasm the knowledge-building model inspires, its emphasis on collective work is difficult for teachers and students alike. Whereas many knowledge-building studies report on experienced teachers, this paper examines the challenges facing new teachers as they gradually make changes towards more principle-based designs, and how their students develop more cohesive interactions and productive discourse.

This study has examined the characterization and developmental trajectory of knowledge-building discourse in the context of how two teachers move towards more sophisticated knowledge-building design over time. The first question examined the teachers' change from activity-based to principle-based and from individual to collective designs. A key theme is that the two teachers, working with the researchers and the teacher network, were engaged in a design-based process, examining student problems and advances while making needed refinements. The teachers' initial design restricted the number of questions students posed; the results showed spider-web patterns that reflected students' beliefs about how questions are to be answered and other related problems, such as repetitive responses and lack of explanation. Examining these debilitating patterns may help new teachers to understand key principles of knowledge building, and to emphasize epistemic agency and community knowledge. There are various ways in which the teachers worked with students, employing key principles, such as helping students to identify productive areas of inquiry for improvable ideas. Figure 1 shows the gradual progression of student work on KF – from spider web (Fig. 1a), to divergent responses (Fig. 1b), to an integrated view (Fig. 1c); and there were changes from using a paper-pencil concept-map to KF reflective assessment with reference notes reflecting attempts towards a meta-discourse. At various phases, the teachers were concerned with continual refinements and how their students' work could be improved. The two new teachers worked closely supporting each other; their patterns of results suggest both

made progress over the years. Examining how new teachers adapt different designs and grappling with principles may have implications for knowledge-building design and professional development.

Another key theme of this paper characterizes the nature and development of the knowledge-building discourse through examining knowledge-building practice at different times. The second question examined knowledge building participation and discourse among the children over the two-year period. Quantitative and qualitative analyses show that children in Year 2, compared to Year 1, participated more actively on Knowledge Forum, with increased community connectedness, and they were more engaged in productive discourse. These results suggest that changes in teacher practice using principle-based design might have helped to bring about more community cohesion and sustained discourse in the class community. The third question indicating the relation between Knowledge Forum engagement and domain understanding is reassuring to the teachers; the results are consistent with other studies conducted in Hong Kong classrooms (see Lee et al., 2006).

Analyses indicate discourse of school children in Hong Kong can be differentiated into different types including knowledge sharing, knowledge construction, and emerging knowledge creation (van Aalst, 2009). For knowledge sharing, children are interacting but they are involved with sharing opinion with little explanation or evidence. Knowledge construction suggests their efforts to develop some understanding; question-explanation is important discourse moves. For emerging knowledge creation, it seems that even elementary school students can engage in scientific discourse, reflecting efforts towards collective inquiry and theory building and the notion that ideas and theory can be tested and revised through experimentation. The changes among teachers and students over the two years suggest possible developmental progression that has theoretical and design implications. The different kinds of discourse threads can be employed by teachers for examining students' work and scaffolding students towards more productive discourse. Further investigation can be conducted to investigate how teachers shift from procedures to principles as they scaffold their students to change from knowledge-sharing towards explanatory-based knowledge-creation discourse.

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