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Beyond group collaboration: Facilitating an idea-centered view of collaboration through knowledge building in a science class of fifth-graders

Abstract. This study investigates the effects of knowledge building pedagogy and technology (i.e., Knowledge Forum, KF) on students' collaborative competencies and their views on collaboration over 18 weeks. Participants were 52 fifth graders from two science classes (n=26 for both the experimental and control classes). Data mainly came from students' online activities recorded in a KF database and pre-post interview regarding students' views on collaboration. Findings indicate that engaging students in knowledge building enhanced students' collaborative competencies; they become more socially interactive and were able to collaborate more opportunistically beyond pre-determined, fixed groups. Moreover, it was found that engaging in knowledge building also broadened students' view of collaboration, enabling them to see collaboration not just from a task-driven, group-based perspective, but from a more emergent, idea-centered perspective. Implications for science instruction are discussed.

Keywords: Idea-centered collaboration, knowledge-building, science learning, group collaboration

Introduction

Scientific knowledge is socially constructed (Bereiter, 2002; Driver, Leach, Millar, & Scott, 1996; John-Steiner, 2000; Kuhn, 1970; Latour & Woolgar, 1986; Merton, 1973; Popper, 1972; Thagard, 1997). As noted by Merton (1973), collaborative practice is essential in the field of natural sciences (see also Latour & Woolgar, 1986). In support of Merton's claim, Thagard (1997) further found that most research work in natural sciences is collaborative in nature; even back in 1950's, more than 80% of published research in natural sciences were co-authored. Being able to collaborate with peers has become increasingly more important in a modern society, especially in a knowledge-based economy where the demand of new knowledge is ever-increasing (Crook, 1998; Trilling & Hood, 1999; UNESCO, 2005). Yet research also indicates that students have little understanding of science as a collaborative enterprise (Driver et al., 1996) and of the importance of scientific collaboration for creating new knowledge (Smith, Maclin, Houghton, & Hennessey, 2000). As Driver et al. (1996) point out, the predominant view of science is that of the individual scientist undertaking his or her work in isolation (e.g., in a lab). Helping students develop more informed views of science as a collaborative enterprise, however, plays a central goal in science education as such views constitute an important part of scientific literacy (AAAS, 1993; NRC, 1996). Accordingly, the purpose of this study is to help students develop a more informed view of collaboration. In the work reported, I introduce two types of collaboration—group-based and idea-centered—and discuss about the rationale that underlies them. It will then be followed by a proposal of using knowledge building pedagogy and technology as a means to helping students develop a more informed view of collaboration for science learning.

Two types of collaboration

In a review on the research history of collaborative learning, Dillenbour, Baker, Blaye, and O'Malley (1996) found that theories of collaborative learning tended to focus on how individuals function in a group (i.e., learning in group), or how group itself functions as a work unit (i.e., learning by group). Either way, group-based activities are highly valued. Recent studies, however, indicate that collaboration may not necessarily have to be group-based; it can go beyond groups (Biehl, Baker, Bailey, Tan, Inkpen, & Czerwinski, 2008; Hong & Sullivan, 2009; Moreno, Vivacqua, & de Souza, 2003; Zhang, Scardamalia, Reeve, & Messina, 2009). For example, in a three-year study, Zhang et al. (2009) found that with teacher guidance, elementary students were able to shift their classroom learning from fixed small-groups (year 1), to more interactive small-groups with substantial cross-group knowledge sharing (year 2), and to more emergent collaboration without any explicit form of grouping (year 3). As also noted by Moreno, Vivacqua, and de Souza, (2004), in a networked learning environment, because individuals usually work behind their personal computer terminals, their collaboration tend to be unplanned and opportunistic, and it can be helpful to design some kind of mechanisms to facilitate the process of such opportunistic collaboration.

Group-based collaboration

The practice of group-based teamwork perhaps has its origins since the industrial age (Scott, 1986), during which the assembly-line type of production and teamwork have been playing an essential role in deciding how individuals work together. Under such teamwork, mastery of one’s own part of work in order to achieve maximum efficiency in team production is usually considered the norm. Corresponding to such teamwork in industry, cooperative or collaborative learning in schools also highly values group-based activities. Oftentimes, students are assigned well-defined roles and asked to complete a whole task by doing parts of it (i.e., subtasks) based on the nature of that task (Slavin, 1983). Such group-based, task-driven concept of teamwork has been deeply rooted in school learning. For example, a well-known instructional approach using group-based collaborative learning has been the jigsaw method (Aronson & Patnoe, 1997). Its rationale is that each group represents one piece of the puzzle, and together they can contribute to a complete understanding of the whole puzzle (see also Brown & Campione, 1996). As noted by the authors in their book, ‘‘The Jigsaw Classroom:’’

> Every member of every group was responsible for learning all the curriculum material, but individual students had direct access to only their part of the material—the part they were to teach others. Since they had to depend on groupmates for access to the rest of the materials, it became essential for all groupmates to do a good job of communicating their parts of the material…In essence, the students in each group were putting their knowledge together a piece at a time, each student contributing a piece of the jigsaw puzzle of material. (p. 91)

Clearly, such kind of collaborative learning represents an effective way to complete a given task quickly; and to implement such collaboration, it is helpful to create well-defined class structures and group activities in order to achieve more effective and productive learning.

Idea-centered collaboration

In contrast with group-based collaboration, an alternative way of collaboration that goes beyond fixed groups is perhaps idea-centered—a unplanned, non-group-based, emergent, self-organizing, and opportunistic way of working collectively and creatively in a team or community (Biehl, Baker, Bailey, Tan, Inkpen, & Czerwinski, 2008; Hong & Sullivan, 2009; Moreno, Vivacqua, & de Souza, 2003; Zhang, Scardamalia, Reeve, & Messina, 2009). Underlying such collaboration is a rationale that sees ideas as fundamental knowledge units or conceptual artifacts (Bereiter, 2002) that belong to what Popper (1972) called "World 3". Other than World 1 (the physical world) and World 2 (the subjective world inside the mind), Popper postulates a World 3 that is constituted of conceptual artifacts. The ideas and theories created by knowledge workers such as scientists, engineers and architects are among the conceptual artifacts. These theories and ideas, once created, have a life of their own in that they can be improved and transformed by people who work on and interact with them. They are treated as tentative theories that are subjected to sustained advancement. A unique feature of idea-centered collaboration is to foster knowledge construction rather than just knowledge acquisition (Hong, Scardamalia, & Zhang, in press; Hong & Sullivan, 2009; Paavola, Lipponen, & Hakkarainen, 2004). Examples of such collaboration can be commonly found in research, science, technology, and business communities (Evans & Wolf 2005; Gloor, 2006; Latour & Woolgar, 1986; Merton, 1973; Nonaka, 1994; Nonaka & Takeuchi, 1995). In these communities, collaboration is emergent because of the need for creating new knowledge or generating fresh ideas. Take technology community for instance, it was found that new technologies are increasingly created by self-organizing knowledge workers (Rycroft, 2003) such that the open source operating system, Linux, has been developed and continues to evolve through an essentially volunteer, self-organizing community of thousands of programmers who collaborate on diversified ideas through constant exchange of open source code without any obvious form of grouping (Evans & Wolf, 2005).

Knowledge building theory and technology

One way to help students develop a more idea-centered view of collaboration may be to engage students directly in a collective 'theory-building' process (Carey & Smith, 1993) and one of the most effective ways to foster such "theory-building" process has been "knowledge building" (Scardamalia & Bereiter, 2006). Knowledge building is defined by Scardamalia and Bereiter (2003) as a social process with focus on the production and continual improvement of ideas of value to a community (Scardamalia & Bereiter, 2003), and is supplemented by the use of a software program called Knowledge Forum. Instead of collaboration based on pre-defined groups, knowledge building process emphasizes collaboration based on ideas as emergents. As ideas may emerge from anyone and anywhere, and can be further worked by anyone who is interested in them, defining knowledge work by fixed groups may limit the possibility of idea advancement. To facilitate emergent collaboration, knowledge building employs a set of principles (see Scardamalia, 2002, for details). These principles help guide instruction to move away from knowledge work that is usually defined by pre-specified procedures, tasks and groups, to knowledge work that encourages sustained idea production and improvement (Hong & Sullivan, 2009). For example, the principle of 'Idea Diversity' emphasized that diversified ideas as essential to solving real-life problems as biodiversity is to the success of an ecosystem; and the principle of 'Improvable Ideas' highlights that participants view their generated ideas as improvable; they work to improve the quality, coherence, and utility of ideas in their shared knowledge spaces (Scardamalia, 2002).

Previous research suggests that the integral use of knowledge-building pedagogy and technology has been an effective means to support more interactive learning activities in class settings (Hong, Chen, Chai, & Chan, in press; Scardamalia, 2002; Scardamalia, Bereiter & Lamon, 1994; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). As such, engaging students in such environments perhaps also has effects on their views of collaboration. Yet, such assumption remains to be tested, especially in the Taiwanese society. The purpose of the present study is thus to investigate the effects of knowledge building on students' collaborative learning process and outcome. Specifically, the present research intends to answer the following two main research questions: (1) Whether engaging students in knowledge building would facilitate them to work beyond group collaboration (a process perspective); and (2) Whether engaging students in knowledge building would help students develop a more informed view of collaboration (an outcome perspective)?

Method

Participants and context

Participants were two classes of fifth-grade students (N=52) sampled from a pool of eight fifth-grade classes in an elementary school in Taipei. Most of them were from low-to-middle income families. Prior to this study, they have been taking computer classes for 2 consecutive years, on a once-a-week 40-minutes-each-time basis. All of them were thus able to operate a computer, use Microsoft Word and PowerPoint, perform search on Internet, and type in Chinese. The two selected classes were randomly assigned to a control class (n=26) and an experimental class (n=26). As baseline comparison, analysis on students' academic scores from the previous year was conducted, and no significant difference was found between the two classes ($F = .486$, $df = 51$, $p > .05$). The whole duration of the study was eighteen weeks, and they can be divided into two phases. In phase 1 (weeks one to nine), the main topic of inquiry was light and the sub-topics to be inquired included (a) the nature of light, (b) how light travels, (c) different lenses, (d) types of eyeglasses, (e) the relationship between light and human eyes, and (f) light pollution. In phase 2 (weeks ten to eighteen), the main topic of inquiry was sounds and the sub-topics to be inquired included (a) the nature of sounds, (b) how sounds travel, (c) different types of sounds, (d) music instruments, (e) the relationships between sounds and human ears, and (f) noise. Both main topics (light and sounds) for learning were government-approved curriculum materials designed for this (fifth) grade level. In each week, students spent one class-session (40 minutes) engaging in their science inquiry.

Instructional design and learning environments

Efforts have been made to ensure that the two classes were comparable. For example, both classes were taught by the same teacher, employed the same curriculum guidelines and materials, spent the same amount of time in learning, and were required to complete and present inquiry projects, as well as be tested about what was learned, at the end of the semester. All instructional activities were designed to be the same except that students in the experimental group were engaged in knowledge building, while the control class adopts a group-based learning using the Jigsaw method (Aronson & Patnoe, 1997). The immediate instructional goal was to help students learn the curriculum materials and the long-term goal was to help them produce a science project for a coming science fair within the school in the following year. As such, students were explicitly encouraged to emulate the role of scientists working together on a project since the start of this study. In terms of grouping, a conventional class routine followed by the participating teacher is to divide his students into groups in the beginning of school year, and then to implement all instructional activities based on these pre-determined, fixed groups. Accordingly, students in both the experimental and control classes were respectively assigned into one of six pre-determined groups, with each group having three to five students. The teacher then had students in the same group sit around a big desk in order for students to perform group work together. In the present study, although both the experimental and control classes employed this grouping convention in the beginning of the study, it was expected that students in the experimental, knowledge building class would be able to go beyond group collaboration and demonstrate more idea-centered characteristics of collaboration towards the end of this study.

As for the learning environment, the control class represented a conventional one with focus on structured group-based collaborative learning, using Jigsaw instruction (Aronson & Patnoe, 1997). Specifically, it was implemented by means of selecting a learning task (i.e., investigating sounds), defining the whole content of the task to be learned, dividing the whole task into sub-topical components, then having each of the six groups adopt and master one sub-topic (e.g., how sounds travel), and finally teaching other groups by making a presentation in class. Namely, each group shared its piece of knowledge with the other five groups like working on a puzzle.

In contrast, while the experimental class also started with six pre-determined groups, engaged in scientific inquiry, and were also required to complete and report inquiry projects as well as be tested about what was learned at the end of the semester, their learning process was facilitated by knowledge building pedagogy and technology (i.e., Knowledge Forum, KF). In brief, KF is an online platform that runs on a multimedia database. It allows users to simultaneously create and post their ideas in the form of note into the database, read postings, reply to other users' notes, search and retrieve records, and organize notes into more complex conceptual representations. KF runs on both a text-based and graphics-based mode. In the graphics mode, it shows linkages of postings as a way to represent the interconnectivity and dialogical nature of knowledge. It also enables the development of ideas to be traced. Figure 1 shows a KF view (i.e., an open space designed for collaborative problem-solving), within which users are guided to work as a community by posting their problem of interest, producing initial ideas for problem-solving, sharing, connecting and revising ideas, synthesizing their ideas, and deepening their collective understanding of problems at issue.

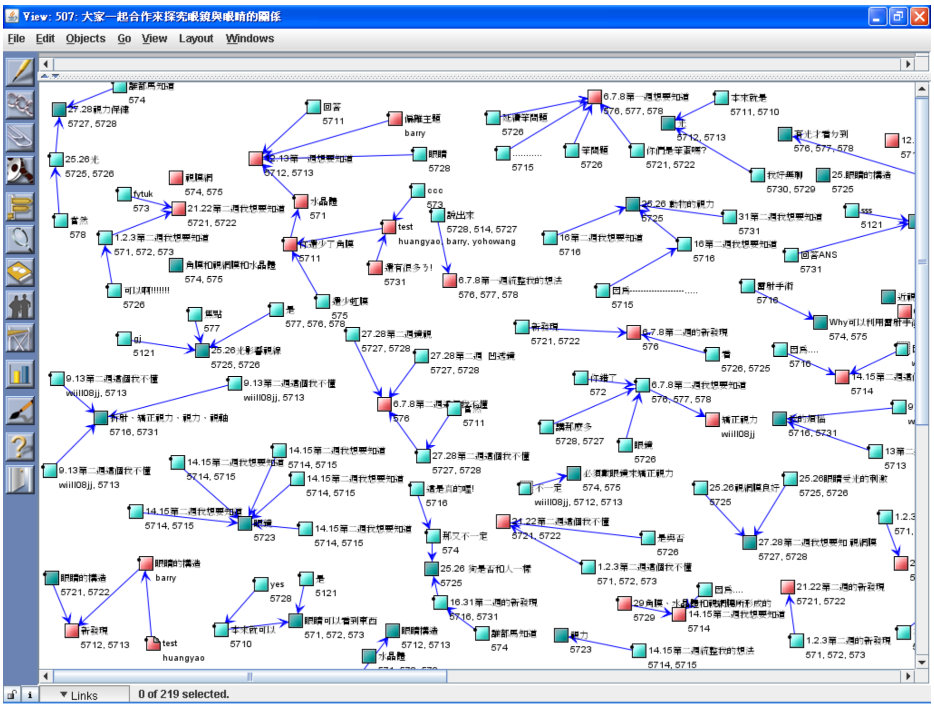


Figure 1: A screenshot of participants working on a topic regarding light and eyes in a Knowledge Forum view

In terms of procedure, both the experimental and control classes followed the curriculum guidelines (about light and sounds) for instruction. The main difference in instruction is how they work with laptops for learning. There were in total twelve laptops available for use at all time for both conditions. The experimental class mainly used computers for their weekly work in Knowledge Forum. Students used them to ask questions and formulate problems, generate ideas for solving problems and answering questions, exchange ideas (i.e., information, evidence, counter-evidence, better solutions, experiment results, etc.), and improve ideas by providing better explanation, or alternative explanations, etc. In contrast, students in the control group mainly used them for group project work, for example, online search, word processing, and preparing presentation slides. Building on the Jigsaw method, their collective goal is to master the textbook content knowledge about light and sounds.

It is important to note that although the participating teacher was an experienced science and computer teacher for ten years, he had no prior knowledge about knowledge building pedagogy or experience of using Knowledge Forum. So regular professional development sessions were provided on a weekly basis, with around 30 minutes each time, to help the teacher be familiar with knowledge building pedagogy and technology.

Data source and analysis

As argued by Dellinger and Leech (2007), the advantage of mixed methods is being able to capitalize on the juxtaposition of quantitative and qualitative ways. Accordingly, the present study collected data from multiply sources as follows: (1) students' knowledge building activities recorded in a Knowledge Forum database, and (2) group interview. In terms of the first dataset, this study looked into students' (1) overall online behaviors, (2) interactive patterns, and (3) collaborative learning outcomes in Knowledge Forum. First, to analyze students' overall online behaviors, descriptive analysis was employed on the two most fundamental online indicators: note-contribution and note-reading. Then, social network analysis (Wasserman, & Faust, 1994) on note-reading and note-linking (e.g., building-on and referencing a note) was computed to explain the online social dynamics, by using the following three measures: (1) connection, which is defined as a tie between two students (e.g., reading or linking a note); (2) density, which is defined as the proportion of connections in a network relative to the total number possible; the higher the density value of a network is, the stronger the social dynamics of that network is implied; and (3) betweenness centralization, which is defined as the degree of inequality or variance in a network; the higher its value is, the higher degree of inequality implied in that network (for details, see, Hanneman, 2000). As the goal in the present study is to facilitate collaboration beyond pre-defined groups, it is expected to see more connections, higher network density, and lower betweenness centrality towards the end of this study. Third, content analysis was performed to examine students' collaborative learning outcomes in Knowledge Forum. A coding scheme was adapted from Zhang et al. (2007) featuring two basic types of questioning/answering: (1) factual, i.e., questions to be answered with factual information (who, when, where, when, how many, etc.); (2) explanatory: i.e., questions answered with an explanation (how, why, what-if, etc.). Table 1 shows some examples of factual and explanatory questioning/answering excerpted from student online discourse. Two coders, who were both graduate students, independently categorized each question into one of the two question types. An inter-coder agreement was calculated as the percentage of agreement between two coders for each question type pre-determined, with differences resolved by discussion; the result was 93%.

Table 1. Examples of factual and explanatory questioning/answering excerpted from student online discourse (Translated from Chinese)

	Questioning	Answering
Factual	What is a retina?	It is a membrane covering the back wall of the eyeball.

	What is a decibel? Can fish hear sound?	A unit that measure the intensity of sound. Yes.
Explanatory	Why do people become nearsighted? How do convex lens burn paper? Why will eardrum get hurt when listening to a very loud stereo?	It is because the eyeball is longer than usual or because there is an abnormality of the lens. A convex lens burns a piece of paper by concentrating sun's rays in a focal point (best to use black paper as it absorbs heat quickly). It is because the membrane in the ear will vibrate to sound so severely that it gets damaged.

In terms of students' view on collaboration, group interview was conducted (Frey & Fontana, 1991). There were a few reasons for using groups rather than individuals for interview. First, as mentioned above, it is because there is a convention in the participanting classes to divide students into fixed groups for science instruction; as such, all class learning and instructional activities were also conducted based on groups. This study capitalized on this convention when conducting interviews so as to make students feel more comfortable being interviewed as it resembles their routine group discussion in class. Also, the data collected will be based on their authentic group experiences. Second, it is because the main interest of this interview was to explore students' views on collaboration, using group as unit would help us elicit students' view that comes directly from their immediately belonged group interaction. The interviews were administered twice, one in the beginning and a second time at the end of the study. As each class has six pre-defined groups, the total number of groups is twelve, with each group constituted by three to five students. For this particular study, we assigned each group a group ID (i.e., G1-G12). The interview was semi-structured, focusing on the following two main dimensions: whether and how scientists collaborate. An interview protocol is shown in Table 2. To conduct interview, the researcher asked questions to the group first and then facilitated each student to express his or her view by taking turns. All interview processes were video-taped. The time for each group interview was about 20 minutes. All videotapes were transcribed verbatim, and then content-analyzed using students' utterances as unit of analysis (Strauss & Corbin, 1990). Two coders independently categorized each student utterance into a code of the coding scheme. Inter-coder agreement (=91%) was calculated using the formula: Number of Agreements / Number of Agreements + Disagreements. Differences were resolved by discussion. Table 3 shows the coding scheme emerged from an open-coding process which involves "breaking down, examining, comparing, conceptualizing, and categorizing data" (Strauss & Corbin, 1990, p. 61). As a result, two main codes highlighting task- and person-oriented teamwork emerged for group-based collaboration; another two codes highlighting idea-generation and idea-improvement emerged for idea-centered collaboration. To analyze, an approach of quantifying qualitative analyses of verbal data developed by Chi (1997) was adopted to calculate the total number of utterances in accordance with a main theme. As our total group samples (n=12) is few, nonparametric tests (Mann-Whitney U test and Wilcoxon signed ranks test) were employed to measure pre-post change in students' views of collaboration and to test if there were any differences between the control and experimental classes.

Table 2. Interview protocol

Dimension	Sample questions (Translated from Chinese)
Whether scientists	How do scientists usually work? Do they usually work alone in the

collaborate	science lab, or do they work together with others? How does scientific knowledge in textbook come from (e.g. from individual genius or group work)?
How scientists collaborate	Do scientists interact with other scientists? If so, why and how? Do scientists need to learn about what other scientists are doing? If so, why? How do scientists usually collaborate (if they collaborate)? What is the purpose of collaboration?

Table 3. Coding scheme for collaboration

Category	Theme	Example (Translated from Chinese)
Whether scientists collaborate	Yes	Scientists like to collaborate. Division of labor is a good way for collaboration. (G12)
	Not necessary/no need	Scientists do not necessarily have to collaborate. (G10) Scientists do not collaborate. (G1)
How scientists collaborate	Group-based	
	1. Task-orientation	Scientists conduct experiments based on the nature and content of task. (G7)
	2. Person-orientation	They decide who to do what based on ability; a person with stronger ability should do more difficulty work. (G10)
	Idea-centered	
	1. Idea-generation	Have a discussion or conversation with others and then write down each one's own ideas. (G12)
	2. Idea-improvement	A scientist may try to combine his ideas with another scientist's idea to create a new or better idea" (G11)

Results and discussion

Online performance in Knowledge Forum

To understand whether engaging students in knowledge building help students progressively become more collaborative and eventually be able to collaborate beyond fixed groups, we explored students' (1) online behaviors, (2) interactive patterns, and (3) collaborative learning outcomes in Knowledge Forum. They are elaborated as follows.

Overall behaviors

This study first analyzed student' online behaviors (Table 4) from phase 1 to phase 2, in terms of two fundamental behaviors: note-contribution and note-reading. In terms of note contribution, on average each student contributed a mean number of 11.54 notes in phase 1 and 10.58 notes in phase 2. A t-test showed no significant difference between the two phases, indicating a consistent note-contribution behavior across both phases. In terms of note-reading, each student on average read a mean number of 13.36 notes in phase 1 and 51.24 notes in phase 2. A t-test showed a significant difference between the two phases, indicating a gradually more active information-sharing behavior toward the later phase. Overall, these two behavioral measures gave a general picture of how participants worked online in this database. However, they tell little about how participants actually interacted with one another. To better understand the social dynamics in the community, a social network analysis (SNA) was conducted.

Table 4. Descriptive analysis on two basic online activities in the community

	Phase 1	Phase 2	t-value

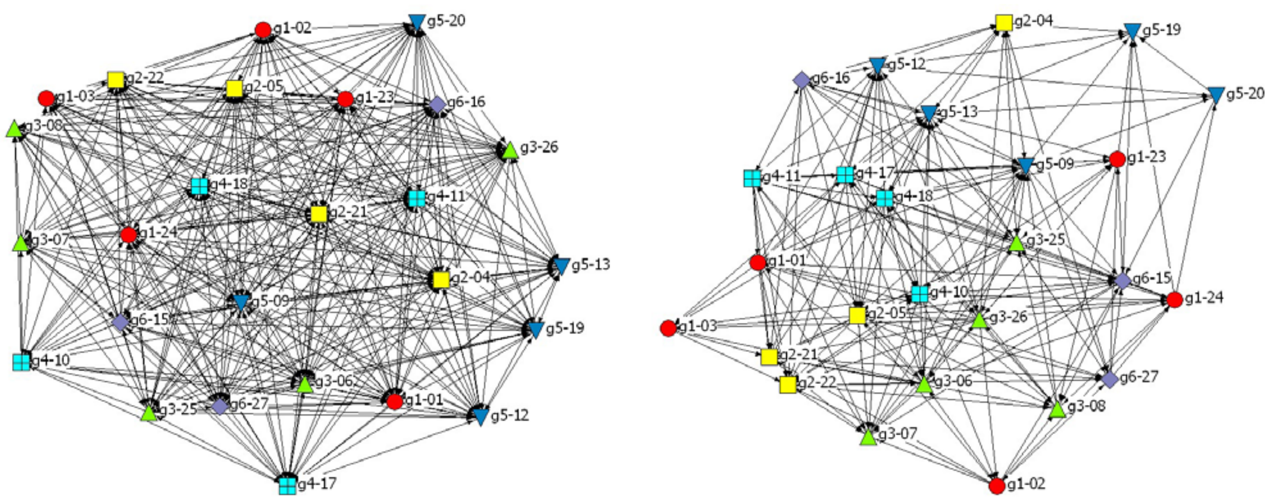
Dimension	Mean	SD	Mean	SD	
No. of total notes contributed	11.54	4.02	10.58	5.25	.78
No. of notes read	13.36	6.79	51.24	33.74	-4.45***

P <.001

Interaction patterns

Figure 2 shows the overall patterns over 18 weeks, using two main indicators: “note-reading” and “note-linking”. While both are important social mechanisms, they serve different roles in Knowledge Forum. The purpose of the former focuses more on sharing ideas while that of the latter focuses more on building on and improving others’ ideas. In this Figure, every node represents a class member; nodes with the same color/shape indicate members from the same group pre-decided in the beginning of the class; the node label indicates group and student ID numbers; for example, g1-01 means a member of group 1 with a student ID as 01. In Figure 2a, it shows that nodes from the same groups were not clustering together, suggesting that students seemed able to read each other’s notes beyond their belonged group. In contrast, in Figure 2b, from the fact that nodes from the same groups were more adjacent to each other, it suggests that students’ note-linking activities were relatively more limited to their pre-determined groups (e.g., see groups 3 and 4, nodes were clustering together). But even so, Figure 2b shows that students were able to work with other members across groups.

To analyze further in depth, changes in students’ interactions from phase 1 to 2 were documented. As Table 5 shows, regardless of note-reading or -linking activities, there was an increasing trend in terms of the number of connections and network density from phase 1 to 2. In addition, it can be seen that there was a decreasing trend in betweenness centrality from phase 1 to 2. The overall network centralization in phase 2 was relatively lower than that in phase 1. This suggests that members in this network in phase 2 can make connections without much the aid of any intermediator, therefore there were not a lot of "betweenness." In other words, there was less inequality, or not a lot of "power", in this network, in the second phase. This also suggests that students’ collaboration was less likely to be limited within pre-defined groups or that they were more able to exchange ideas by reading or linking to other peers’ notes beyond groups. All these quantitative online behavioral and interactive measures indicate that students were progressively able to collaborate beyond groups. Next we further look into collaborative learning outcomes in Knowledge Forum from phase 1 to 2.



a. Note reading patterns among students b. Note linking patterns among students

Figure 2. Online interaction patterns in Knowledge Forum

Table 5. Social network analysis (SNA) in terms of connections and density in this community (n=26)

indicators	Phase 1	Phase 2
Note reading		
No. of connections	380	544
Network density	58.46%	83.69%
Centrality (betweenness)	5.12%	0.74%
Note linking		
No. of connections	212	242
Network density	32.62%	37.23%
Centrality (betweenness)	9.24%	5.58%

Collaborative learning outcomes

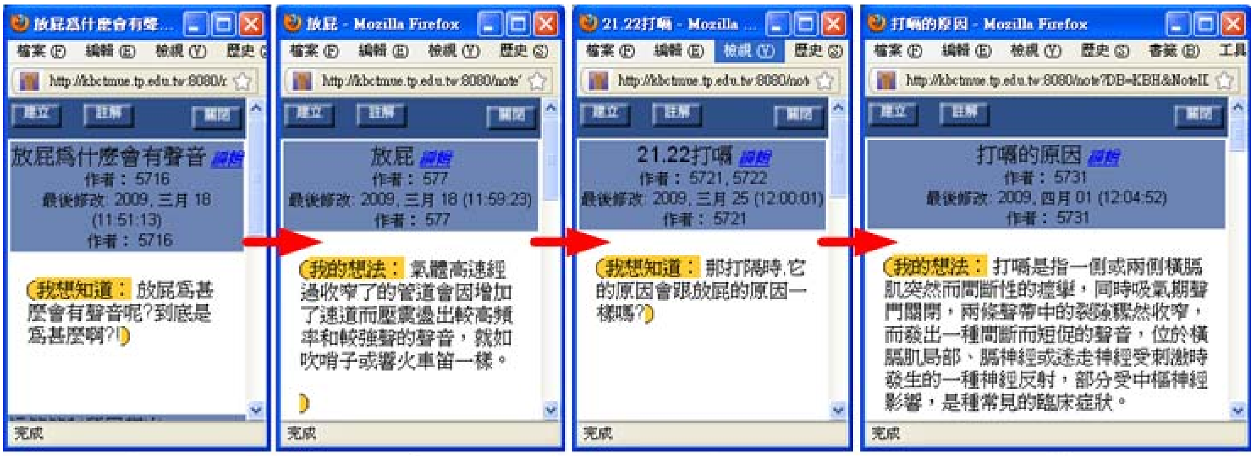
To further explore students' online performance in Knowledge Forum, content analysis on students' online discourse pertaining to their questioning/answering behaviors was examined. First, in terms of questioning, it was found there were in total 68 questions being asked in Knowledge Forum in phase 1, but there were only 32 questions raised in phase 2. This indicates a broader scope of collaborative inquiry in phase 1 than in phase 2. Further, in terms of question type, it was found that consistent in both phases, students tended to ask more explanation-based questions (i.e., why, how or what-if questions) than fact-based questions (i.e., what, when, or whether questions) for both phases. In phase 1 there was 61.8% of explanation-based questions v.s. 38.2% of fact-based questions; and in phase 2, there was 62.5% of explanation-based questions and 37.5% of fact-based questions.

Second, in terms of answering, it was found while the total number of answers being collectively generated and discussed online was about the same (15 and 14 answers in phases 1 and 2, respectively), the overall percentage of the questions that got answered is much higher in phase 2 (43.75%) than in phase 1 (22.05%). In contrast to the above finding that features a broader scope of inquiry in phase 1, this suggests a relatively more focused collaborative inquiry in phase 2 than in phase 1. For instance, below are two examples of collective inquiry excerpted from phases 2 (Figures 3 and 4). In Example 1 (translated from Chinese), first, there were two students from a same group initiated a question about sound: "Why on earth there is sound?"(Figure 3a); then, this was followed by another two students from another group who helped explain the nature of sounds being a kind of wave passing through a media such as air (Figure 3b); and finally, two more students from another group made an inference that as there is hardly any air in the space, it is unlikely to hear anything there (Figure 3c). In total, there were six students from three different groups joined discussion about why on earth there is sound in Example 1. In Example 2 (translated from Chinese), first, there were two students from a same group initiated a question as to why passing a wind makes a sound (see Figure 4a); then, someone from another group joined and helped to explain that it is because when gap passes through narrow (anal) opening it increases the velocity of expulsion of the gas and thus making higher frequency and stronger noise (Figure 4b); then, another two students from another group further asked whether burping shares the same cause with farting in terms of producing sound (Figure 4c); finally, another student from another group made a more detail explanation by referring to some medical information in a website (Figure 4d). In total, there were five students from 4 different groups joined to discuss about why passing a wind makes a sound in Example 2.

Overall, the above three different set of analyses on online performance (i.e., online behavior, SNA, and collaborative learning outcomes) indicates that students were able to gradually work together beyond group collaboration. Next we further look into whether students were also able to change their views on collaboration.

3a 3b 3c

Figure 3. Student online discussion about why on earth there is sound (Example 1)



4a 4b 4c 4d

Figure 4. Student online discussion about why passing a wind makes a noise (Example 2)

<u>Students' views on collaboration</u>

To understand whether engaging students in knowledge building also helps them develop a more diversified view of scientific collaboration, we content-analyzed students' group interview data and then illustrate how their views of collaboration changed over time.

<u>Whether scientists collaborate</u>

Figure 5 shows pre-post changes in students' view on whether scientists collaborate. First, as baseline comparison, a statistics test using only pre-assessment data was conducted and it showed there was no significant difference (Mann-Whitney $U=17$, $p>.05$) between the control and experimental groups. Second, Wilcoxon signed rank tests were conducted to measure changes from pre-assessment to post-assessment within the control and experimental classes, respectively; significant increases were found for both the control group ($p<.05$) and the experimental group ($p<.05$). Finally, an additional comparison between the control and the experimental classes in terms of the extent of their pre-post change was conducted and it was found there was no significant different between the two classes (Mann-Whitney $U=10.5$, $p>.05$). This suggests that conventional group-based instruction and knowledge building instruction were both effective in helping students see the importance of collaboration in scientists' knowledge work. Arguably, this may be because both groups were practicing collaboration in class, although in different kinds.

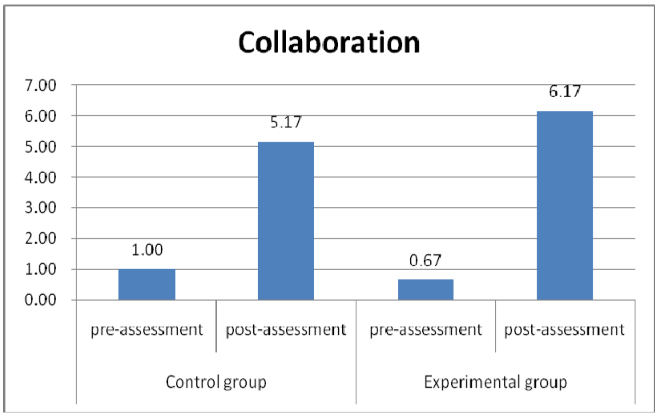


Figure 5. Pre-post changes in students' view on whether scientists collaborate (n=12)

How scientists collaborate

In terms of how scientists collaborate, two major views (themes) developed from the coding process were: group-based and idea-centered collaboration. As baseline comparison, we test if there is any difference between the two views among all students. A Wilcoxon signed rank tests was conducted; as a result, a significant difference between the two views was found (N=12, p<.01). Students in general held a much stronger view towards group-based collaboration (M=7.33; SD=3.47) than idea-centered collaboration (M=3.41; SD=1.72). This was however quite expected as idea-centered collaboration is not commonly practiced in the participating science classes before this study. In this particular study, however, we are more concerned about whether there are any differences between conventional and knowledge-building conditions for each specific type of collaboration. They were each elaborated below.

Group-based collaboration. To understand whether the two types of instruction (conventional vs. knowledge building) influenced students' view on group-based collaboration, nonparametric tests were conducted. Figure 6 shows pre-post changes in students' view on group-based collaboration. First, as baseline comparison (only pre-assessment data was used), it showed there was no significant difference between the control group and the experimental group (Mann-Whitney U=17.5, p>.05). Further comparison between the control and the experimental classes in terms of the extent of their pre-post change was conducted and it was found there was also no significant difference between the two classes (Mann-Whitney U=15, p>.05). This finding suggests that neither conventional nor knowledge building instruction had impacts on students' prior view on group-based collaboration.

Provided below are some excerpts from student interview that showed students' emphasis on the importance of collective group work or division of labor (i.e., who does what, etc.). For instance, when asked to give an example of collaboration, a student said, "…in digging up dinosaur fossil, scientists may do some division of labor, they may make someone dig dinosaur fossils, someone paint plaster, someone call the helicopter, and someone moves it up to the helicopter" (G3). And when discussing how to divide labor, students emphasized that it is important to divide labor based on the content or difficulty level of a task (task-driven), or on team member's expertise or personal ability (person-driven). As three different students said: "they can do it alone if it's a simple project. But once the project is complex, team work will be needed." (G1); "scientists decide what to do by themselves and they decide how to divide work based on their own specialization" (G10); and "they decide who to do what based on their ability; a person with stronger ability should do more difficulty work" (G11).

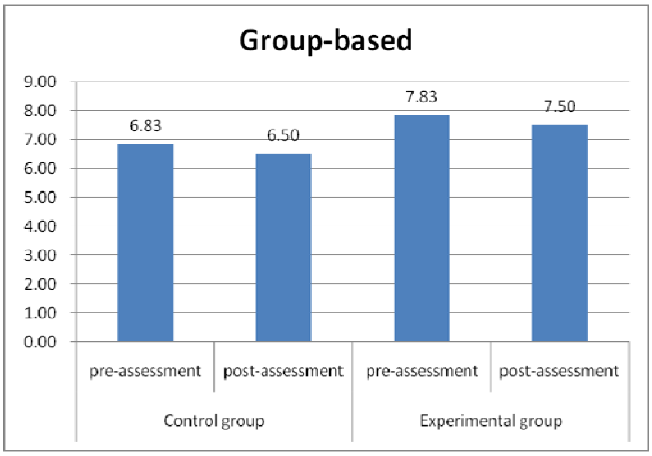


Figure 6. Pre-post changes in students' view on group-based collaboration (n=12)

Idea-centered collaboration. To understand whether the two types of instruction (conventional vs. knowledge building instruction) also have impacts on students' view of idea-centered collaboration, additional analysis was conducted. Figure 7 shows pre-post changes in students' view on idea-centered collaboration. As baseline comparison, a nonparametric test using only pre-assessment data showed there was no significant difference between the control and experimental groups (Mann-Whitney U=8.5, p>.05). Further comparison between the control and the experimental classes, in terms of the extent of their pre-post change, however, showed a significant difference between the two conditions (Mann-Whitney U=2, p<.01), with the experimental class showing a significant pre-post change in students' view on collaboration. The finding suggests that knowledge building pedagogy, as compared with conventional instruction, is more likely to help students develop a more idea-centered view of collaboration.

Provided below are some excerpts from student interview that showed students' emphasis on the importance of idea-centered collaboration. Overall, students mentioned two important aspects of idea-centered work: idea generation and idea-improvement. In terms of idea generation, for example, one student said, "[scientists] discuss together for brainstorming ideas and then research together" (G10). As another student said, "Scientists may put their ideas on Internet to get more ideas from other scientists and they use these ideas to make further inference" (G10). In terms of idea improvement, when discussing how knowledge is advanced, a student said, "They [scientists] may start to work on previous scientists' idea and then continue working on that idea" (G4); as another student said, "A scientist may try to combine his ideas with another scientist's idea to create a new or better idea" (G11). Overall, it is posited that engaging students in knowledge building in which students were able to work with ideas as basic knowledge unit may be a reason to help broaden students' view on collaboration, thus allowing them see that group-based teamwork represents only one way to collaborate and it can be complemented by collaboration around ideas.

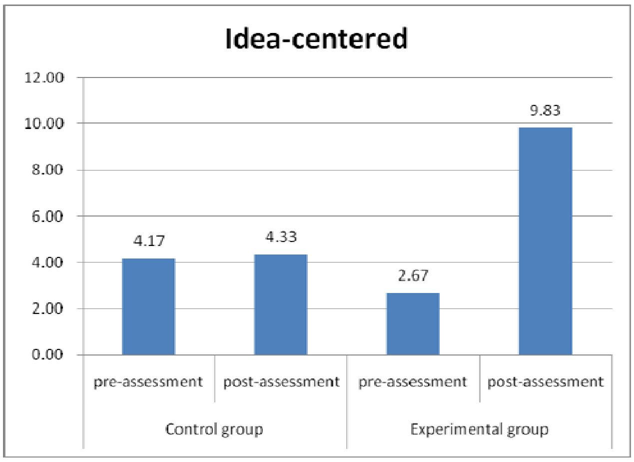


Figure 7. Pre-post changes in students' view on idea-centered collaboration (n=12)

Summary and conclusion

Previous research suggests that the integral use of knowledge-building pedagogy and technology is useful in enhancing social dynamics in class settings (Hong, Scardamalia, Messina, & Teo, 2008; Scardamalia, 2002; Scardamalia, Bereiter & Lamon, 1994; Zhang, Hong, Scardamalia, Teo, & Morley, accepted; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007). This study further suggests that the development of students' views on collaboration can be greatly informed by how they learn (e.g., conventional vs. knowledge building pedagogy) and by the kind of learning environment they are engaged (i.e., group-based learning vs. knowledge building environment). In summary, the findings indicate that knowledge building theory and technology is useful in promoting more emergent and interactive learning activities among elementary students in a science class, and in facilitating them to collaborate more opportunistically beyond pre-defined, fixed groups. More importantly, it was found that engaging students in knowledge building is beneficial to enriching their view of collaboration, making them able to see collaboration not only from a group-based perspective but also from an idea-centered perspective.

The development of socio-cultural theories and related research in the past few decades has gradually transformed the learning focus from an individual approach to a more collaborative approach (Lave & Wenger, 1991; Latour & Woolgar, 1986; Merton, 1973; Rogoff, 1990; Wertsch, 1991; Vygotsky, 1978). Unfortunately, to a large degree, most science learning in schools still highly focuses on individual rather than collaborative learning. Specifically in the Taiwanese context, most students tend to believe that science learning is all about memorizing textbook knowledge, preparing for tests, practicing tutorial problems in order to get good grades (see Tsai, 1998). Consequently, science learning is still more concerned about individual knowledge growth, rather than collaborative knowledge work. Although there is still some collaborative learning practiced in science classes, the kind of collaborative activities observed are inclined to group collaboration that aims to complete clearly-defined tasks, solve well-structured problems, or achieve mastery of certain textbook knowledge; such learning tradition has resulted in less informed views on collaboration among students.

To conclude, the present study provided an initial look at the impact of engaging students in knowledge building on their practices and views of collaboration. We suggest the following areas for future research: First, a major concern by the classroom teacher was that whether engaging students in knowledge building would make students less focused on curriculum materials and thus affect their final science grade. Based on students' final exams on what they learned about light and sounds over the 18 weeks, it was found that there was no significant difference between the two conditions in terms of students' test scores. This suggests that engaging students in knowledge building activities did not negatively affect students' academic performance. While this is the case, it is conjectured that with careful design, engaging students in collaborative knowledge building should be able to even enhance student learning in the content area. The reason why no significant difference was found between the two conditions in terms of students' test scores in the present study may be because what students inquired in Knowledge Forum (KF) was beyond what is tested in textbook (e.g., students discussed in KF whether animals can also became nearsighted; and if so, why?). So, even if students in the knowledge building class acquired more knowledge, it would not be reflected in their test scores. It should be fruitful to continue looking into the relationship between idea-centered collaboration and students' academic performance in future research. Second, it is also conjectured that there may be a relationship between types of collaboration and students' view on nature of science (NOS). Working collaboratively with knowledge around ideas, by brainstorming ideas and collectively improving ideas, in order to solve real-life knowledge problems, implies not only facilitating among students an idea-centered view of collaboration, but also engaging them in an idea-centered education (Scardamalia, 2002). Doing so may be possible to help students develop a more constructivist-oriented epistemological perspective that sees knowledge as tentative and subject to changes (i.e., understanding that ideas are improvable) (cf., Hong & Lin, 2010). Thirdly, we speculate that long-term exposure to idea-centered collaboration may have a positive influence on the development of students' problem-solving capacity. It would be interesting to further investigate how students would solve real-life science problems after engaging students in knowledge building for a longer period of time. Finally, it may be also fruitful to examine the extent of change of students' views on collaboration based on different social interaction patterns in Knowledge Forum. Doing so should help further advance our understanding of the complex relationships between students' views on collaboration and various types of social dynamics.

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