Learning of science in an elementary classroom through Knowledge Building

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Introduction

In Singapore, the national science curriculum for the elementary level aims to provide children with knowledge about the natural world and the skills and processes by which this knowledge is acquired (Curriculum Planning and Development Division, 2004). The success of science education in Singapore is to some degree validated by the performance of Singaporean students in international tests (Gonzales et al, 2004). This success stems in large part from the preference of science teachers in Singaporean elementary schools for approaches that enable them to efficiently deliver the content and teach the skills required in the Singaporean elementary science syllabus (Lee, Tan, Goh, Chia and Chin, 2000).

Knowing the content and skills of science may successfully prepare Singaporean students for examinations and tests, but it may not necessarily translate into success in the field of scientific endeavor in real-life settings. Success in scientific endeavor, especially those at the frontier of science, requires not only knowledge about the content and skills of a scientist, it requires knowledge of how scientists use their knowledge about science to investigate and explain phenomena. Consequently, it is important not only to learn discrete and disembodied pieces of information, but also the knowledge embodied in people and their practices (Brown and Duguid, 2000). The learning of the scientific “know how” and practices of scientists, it is argued, is only possible through the enculturation of individuals in communities of practice (Wenger, 1998). Students, therefore, should not just “learn about science”, but learn “to be” scientists by involving themselves in practices similar to scientist’s communities. This is an achievable task as shown by studies in Canada (Scardamalia, 1996).

Learning science through participation in scientific communities is beginning to come to the fore in Singapore’s schools. Opportunities are now gradually becoming available for students to become participants in community of scientists carrying out research in various institutions (Shanmugaratnam, 2004). These opportunities are yet to be available to science students in elementary schools. New approaches to science education in elementary schools are needed to make available to students the opportunity to learn both the knowledge about science and more illusively the knowledge of how scientists practice science in scientific communities.

An instructional approach that can provide elementary school students the opportunity to develop the “know how” of practicing science is the Knowledge Building approach (Bereiter & Scardamalia, 2003). The approach is modeled on the practices of specialized research groups (Scardamalia & Bereiter, 1996), and seeks to transform classroom communities into Knowledge Building communities. These classroom communities like scientific communities have at their foundations the creation and advancement of knowledge (Bereiter, 1994). The advancement of knowledge in the classroom community is met through the collective cognitive responsibility of members in the community to identify what needs to be known and done (Scardamalia, 2002), similar to the efforts of scientists on research teams. Members in the classroom community share their ideas and engage each other in progressive discourse to improve their ideas (Bereiter, 1994; Scardamalia & Bereiter, 1999) using Knowledge Forum, a technological support for Knowledge Building. This process parallels the peer review and discussion of ideas of scientists reified in the journal publication process.

The use of the Knowledge Building approach has been implemented in schools in various countries including Canada, Finland and Hong Kong. However, the use of this approach is still in its infancy in Singapore. Studies in Singapore have focused on examining the use of Knowledge Forum as a tool to support inquiry-based approaches for learning science in secondary schools (Tan, Hung, & So, 2005; Tan, Yeo, & Lim, in press). There have been none to date that have explored the use of the Knowledge Building approach for learning of science in elementary schools in Singapore.

This study seeks to build on the existing research findings of the use of the Knowledge Building approach and Knowledge Forum in Singapore. The research questions that are explored in this study are:

1. Do students learn knowledge about science using the Knowledge Building approach?
2. What are students’ epistemologies about science using the Knowledge Building approach?

3. What are the contradictions in the activity system that affects knowledge learnt using the Knowledge Building approach?

Method

A mixed-method case study approach was used to explore the use of the Knowledge Building approach in a class of 40 students learning science. A tri-phasic approach to Knowledge Building, which was modeled on similar approaches used in Canada (Casewell & Lamon, 1998; Hewitt, 2001), was used to engage students to construct knowledge on the topic of Energy.

In the first phase, the students carried out four experiments as specified in the school curriculum. Each group was assigned to conduct only one experiment. Students were therefore dependent on the knowledge produced by students in other groups for the knowledge learnt about the topic. This arrangement created a necessity within the class for students to produce viable knowledge products that can be shared with students in other groups. After completing their experiment, the students then answered a question posed by the teacher in Knowledge Forum. For example, the students carrying out the experiment “The Spiral” were asked to “explain how the burning candle caused the spiral to move”; the students carrying out the experiment “Away we go” were asked to “explain how raising the height of the ramp affected the distance moved by the car”; the students carrying out the experiment “Stretch, twist and go” were asked to “explain how your actions made the toy move”; and those carrying out the experiment “The electric circuit” were asked “what happened to the candle wax?” The students were asked to post their first notes that include an answer to the question as well as a question on what they were interested to find out more about or what they needed to know.

In the second phase, the students were required to read each other’s notes and post notes to seek clarification, to elaborate or to suggest alternative ideas. When the students felt that there were ideas that needed further exploration beyond the discourse in the classroom community, they could submit a proposal for literature search or even a proposal to carry out further experiments. This marked the onset of phase three, where the students did further research in response to their questions and ideas to advance the knowledge of the group and class. The results of research in phase three were then posted in Knowledge Forum. Other students would then post responses to this note, thus continuing the process of idea improvement through progressive discourse.

During the course of learning science using the Knowledge Building approach, the students kept a reflection log in which they recorded their actions, the rationale behind their actions, and their feelings about the actions that they undertook. Towards the end of the last phase, the students participated in a written survey, which required them to give their opinions about learning science through the Knowledge Building approach. The students also posted a reflection note in Knowledge Forum at the end of the last phase describing their new theory and the process of arriving at this theory. At the end of the term, the students took a standard test in the school, which included the topic of Energy.

To examine the extent of scientific knowledge acquired by the students, we compared their performance in the school test conducted at end of the term with that of a similar class, which learned the topic of energy through the usual teacher-directed method. We also surveyed the students' opinions about learning science using the Knowledge Building approach. To examine the students' epistemology about science, we triangulated the data from students' reflection notes in Knowledge Forum, their journals and their opinions about learning science using the Knowledge Building approach gathered from the written survey.

Table 1

Data sources used for the analysis of Knowledge learnt

	Data sources		
Knowledge about science	Test scores	Initial and final theories	Opinions from written survey
Epistemology about science	Students reflection notes	Journal entries	Opinions from written survey

Activity theory (Engestrom, 1987) was used as an analytical lens because it enables the systemic description of the activity system, and the surfacing of contradictions within the activity system. Contradictions arise as a result of the introduction and subsequent appropriation of a new influence into the activity system.

Contradictions can exist within or between elements of the activity system and are sources of both perturbations and potential innovations in the activity system.

In this study, contradictions, the structural tensions within the activity system that could have affected knowledge learnt, were explored as possible sources to improve future iterations of the activity. Contradictions within the system were uncovered by examining the visible disturbances within the activity system. The disturbances to the activity of learning science in the class were teased out from the students' reflection notes, journal entries and opinions from written survey.

The activity system that emerged (Figure 1) in the class upon the introduction of the Knowledge Building approach involved the student (Subject) acting on his/her knowledge about energy (Object). The improvement of knowledge about energy was the motive of the activity system. Tools that mediated the actions of a student included traditional tools like textbooks and experiments as well as Knowledge Forum that is new to the students. The student was part of a classroom community. Interactions between students in the community were regulated through informal as well as formal rules. The efforts of the class community at improving their knowledge about energy were mediated through the division of labor that took place when students were grouped according to their research experiments.

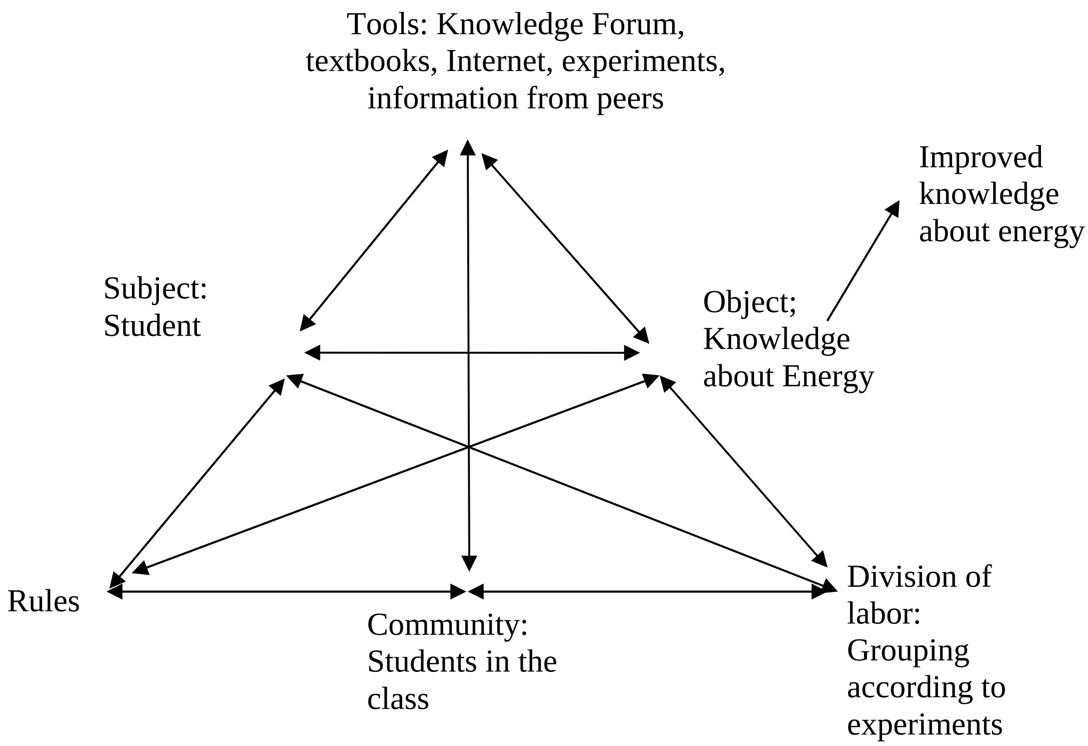

Figure 1. Activity system in the class.

Results and findings

Acquisition of science knowledge

The results of the mean test scores of students in two classes are shown in Table 2. One class used the Knowledge Building approach to learn science, and another did not.

Table 2

Comparison of test scores between two classes

	Class which used the Knowledge Building approach	Class which did not use the Knowledge Building approach
N	38	40
Mean	15.21	13
Std	3.21	2.40

Using t-test, we found a significant difference in the mean test scores between the classes [$t(76) = 2.27$, $p < .05$], with students in the class that learnt Energy using the Knowledge Building approach achieving higher mean score than students in the other class. This is an indication using traditional test as a measurement, students learning science through the Knowledge Building approach were able to learn as much if not more than students learning science using other approaches.

The students indicated in the survey that one of the advantages of this approach to learning science was that it enabled them to "learn new things". The students felt that this approach facilitated the acquisition of both the depth and breadth of knowledge about the topic energy. One student felt that the approach made it "easier to widen my knowledge" while another mentioned that "it helps us to go further deeper about the topic."

The students' notes on their initial and final theories were analyzed to determine the conceptual progress made by the students. We examined the conceptual framework of the explanatory discourse in their notes (see Oshima, Scardamalia & Bereiter, 1996). Thirty one students posted reflection notes, of which 22 students had made conceptual progress. An example of a student who had made conceptual progress shows an initial theory that used descriptions of visible events to explain the movement of a spiral, and a final theory that showed an attempt to explain the spiral's movement through the interactions between heat, air molecules and the spiral.

> Initial theory: "My Theory is that the smoke from the flames causes the spiral to move. the flame's smoke is thick, so when the smoke rises, and the wind blows the smoke, the wind will blow the smoke and push it causing the spiral to move,"
>
> Final theory: "When the candle is being lit up, it produces heat and light energy. The heat energy from the candle cause the air molecules around the air to gain heat energy and make it spread and less dense, causing the it to rise up. When the air molecules rises up towards the spiral, it pushes the spiral causing the spiral to turn, thus the light energy from the candle does nothing."

The results of the students' performance in a school test, their opinions in written survey and comparisons of initial and final theories posted in Knowledge Forum are indicators that the students were able to learn Knowledge about science through the Knowledge Building approach.

Students' epistemology about science

The analysis of students' opinions and reflections about learning science using the Knowledge Building approach revealed that students felt that they had learnt about science from one another through the reading and posting of notes. In their reflective journals, the students also indicated that posting notes were attempts at letting others know what they knew as well as to elicit comments from the community to improve their knowledge. For example, a student wrote "After doing the experiment, I felt that I kind of understand the conversion of energy taking place so I decided to post up my theory, hoping that my theory would help other who weren't that sure of what's going on. I was also hoping that other's could give me suggestions on how to improve my theory as I might be the one who wasn't sure of what's going on."

The intent of posting notes to surface ideas and to seek improvement shows that the students were beginning to demonstrate the tacit "know how" of knowledge advancement and the improvability of ideas in scientific communities.

Students in their written surveys and reflective notes also indicated that the opinions and questions in the notes they read were the impetus for them to carry out their own research and experiments to clarify their doubts and to inform others of new information. Analysis of students' reflection journals supported the findings from the survey responses and reflections notes. One student who investigated electrical circuits wrote this reflection after reading a note responding to his first note:

"He told me that when wax is heated, some of the solid turn into gas. That put me into some thoughts. I decided to do some research and give a better theory."

Another student who investigated on the energy conversions when a toy car rolling down a slope mentioned that she carried out the experiment again to "find out whether there are any other factors which affect the distance moved by the toy car other than the height of the ramp and to gain better understanding of the energy conversions that take place before posting a note on it." After carrying out the experiment she indicated, "I felt quite happy because I could connect what I read up on and the experiment. I also understand the experiment better now." The next day she posted a note in Knowledge Forum indicating her intention, "to share with others my theory and hope that it will contribute to their learning as well as mine."

The illustrations of students doing their own research and experiments to improve their ideas and the subsequent sharing of this knowledge demonstrates the beginnings of students assuming collective cognitive responsibility for finding out and knowing what needs to be done and known to advance their scientific knowledge.

Contradictions in the Activity System

Despite their attempts at sharing their ideas, students revealed in their reflective journals that they felt disappointed about the lack of response to their notes. One student indicated, "I felt disappointed because I posted a note to contribute yet no one posted a note to help me improve my opinion." Another student mentioned, "I was glad that someone answered my question but I was quite disappointed that nobody had commented on my initial note because I will not know what I am wrong and I could not improve on my theory." One student went as far as to indicate in her reflection journal, "Confused? Definitely. Some people's posts were so vague I did not have ANY idea what they were trying to convey."

The lack of responses and the poor quality of responses limit progressive discourse and the advancement of knowledge. This can be interpreted as a disturbance in the learning of Energy by the class using the Knowledge Building approach. This disturbance could have risen from various contradictions in the activity system including, contradictions due to tensions between students in the class and the division of labor in the class community, the research groups; and tensions between rules and the class community (Figure 2).

The division of pupils in the class into research groups was meant to provide opportunity for positive inter-dependence, so that each group could build specialized knowledge that could be shared and built upon by other members of the class. However, the flip side is that it is possible that the use of specialized groups could have polarized the class's efforts in Knowledge Building. Students in the class had experienced working in co-operative learning groups in the past. A strong sense of membership to these groups could have been formed leading to the development of learning communities within the class (Yuen, 2003). Students were thus able to co-operate well in assigned groups to complete tasks and activities. The efficiency with which students could complete tasks and activities and the familiarity with the processes within co-operative learning groups could have resulted in these students focusing only on knowledge built by the group and ignoring notes posted by other groups. Resolving this tension between the division of labor within the class and the class community could be a source of innovation to improve the progressive discourse integral to the Knowledge Building approach.

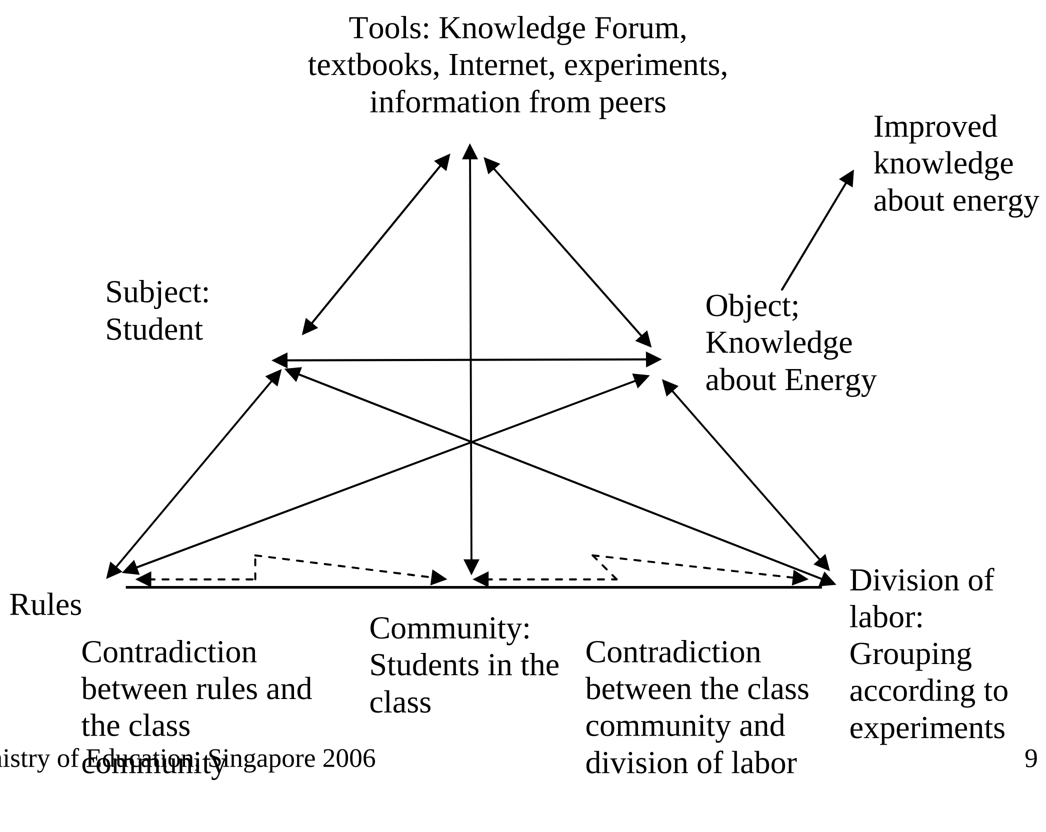

Figure 2. Contradictions in the activity system

The absence of formal rules mediating students' interaction in Knowledge Forum was intended to give students the autonomy to make postings and replies to whomever they wished. This lack of rules however could have resulted in students doing the opposite: the students restricted their posts to their groups possibly due to the sense of membership to their groups. The resulting tension between the lack of rules and class community gives rise to a contradiction that offers yet another source for innovation to improve the progressive discourse process. These contradictions however need to be considered collectively to produce an innovation to the emergent activity system that leverages their possible strengths.

Discussion

Students using the Knowledge Building approach were able to acquire knowledge about science. The acquisition of knowledge can be attributed to the efforts of students in sharing their ideas and seeking improvements to these ideas. It is interesting to observe students appropriating the tools and practices of the scientific community as they orientated their activities towards the improvement of ideas. Although improvements in scientific inquiry process skills were not explicitly studied, it is possible that elementary school students could have improved their process skills like their counterparts in secondary schools in Singapore who used an inquiry approach mediated by Knowledge Forum (Tan, Hung, & So, 2005; Tan, Yeo, & Lim, in press).

In addition to the acquisition of knowledge and skills, students as part of the class community have also begun to demonstrate collective cognitive responsibility for the advancement of knowledge. The demonstration of these processes indicates the beginnings of a Knowledge Building community. The development of the students along the trajectory towards a Knowledge Building community could perhaps be facilitated by exploring changes in the activity system that can improve the progressive discourse of the community.

To enable students to be more participative in progressive discourse, the creation of rules governing the quantity and locus of posts is required. Rules requiring students to not only read and but post notes to other students' experiment notes could result in further clarification of ideas from other members of the class community not represented within the specialized research groups. The introduction of rules could also result in students who are initially not involved in other experiments carrying out their own research or experiments to bring new information into the discourse of students engage in other experiments. The formalization of rules thus has the potential of bringing the Knowledge Building work done by students in their co-operative groups into the progressive discourse of the class community. These rules are not restrictive rules, rather, they could be seemed as a scaffold, which should be removed once the students' habit of contributing to the community is formed.

There are possibly more disturbances arising from other contradictions in the activity system brought about by the introduction of the use of the Knowledge Building approach. Other sources of data need to be brought under the lens of Activity Theory to surface them. The analysis of this data will have be carried out to surface further systemic contradictions that can lead to innovations for improvements of future iterations of the use of the Knowledge Building approach to learn science.

Conclusion

The Knowledge Building approach to learning science has the potential to facilitate students' learning of science. There are however barriers to its adoption that stem from the culture and history of teaching and learning in Singapore. The analysis of contradictions in the emergent activity system of the class has shown to be useful for generating innovation which takes into account the culture and history of teaching and learning in the class. For the pervasive adoption of the Knowledge Building approach in schools in Singapore, it is important to extend the analysis of contradictions from activity systems in solitary classes to the activity systems in schools. The extension of this analysis will result in the generation of innovations with greater systemic impact: overcoming barriers and transforming schools in Singapore to Knowledge Building organizations.

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