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Knowledge Advancement in Environmental Science through Knowledge Building

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Abstract

This paper describes how five elementary school students learnt about environmental science and the nature of science as they were engaged in Knowledge Building (Scardamalia & Bereiter, 2003) during a Nature Learning Camp project. Unlike the emphasis on "doing" in inquiry-based project work, which precludes making cutting edge discoveries by students, Knowledge Building channels students' attention on the continual advancement of group ideas and thus opens the way for appropriating the scientific process of knowledge creation. This is because it takes advantage of a young child's inquisitiveness to develop him/her to become a mature knowledge producer as he/she pushes up his/her level of understanding. In this study, we tracked the knowledge development of this group of students and its process as they studied about plants. Using qualitative discourse analysis, we found advancement in students' ideas about science process skills and the nature of science. However, much support from the teacher was needed for knowledge advancement to take place; the teacher played an important role in engaging the students in sustained talk around the topic and in directing the focus for on their own, students' talk was rather shallow and ideas were fleeting. We conclude that to engage students in Knowledge Building effectively, science argumentation skills are important discourse skills to develop.

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Introduction

Inquiry-based work has been favored as the pedagogical approach to achieve the aims of science learning in many countries (e.g., National Research Council, 2000). Following global trends, the primary science syllabus for Singapore promotes inquiry as *the* framework to achieve the aims of science learning (MOE, 2004, 2007). Typical science inquiry activities take the form of practical work, project work or problem-based learning as these actively involve students in "doing" science like scientists (Greenwald, 2000; Gallagher, Stepien, Sher, & Workman, 1995). While such tasks may mirror some of the work of scientists, the completion of tasks is paramount as is the arrival at similar answers that the teacher has in mind (Tan, 2008). Inquiry-based learning does not capture the knowledge creation enterprise that characterizes the heart of actual scientific practice.

It is here that we introduce an alternative to task-centered inquiry activities known as Knowledge Building. This is an approach to inquiry which places ideas at the center and was first adopted in elementary schools some twenty years ago by Scardamalia and Bereiter for improving reading comprehension in elementary schools. It has since spread to other elementary level subjects, especially elementary science. While the aim of task-centered inquiry is to complete the job given regardless of deep learning, the goal of Knowledge Building work continually at the forefront of their knowledge as they advance the knowledge of their community (Bereiter & Scardamalia, 2003). Such idea-centered activities are said to resemble the theory building practice of scientists better (Bereiter & Scardamalia, 2003).

However, since inquiry has been strongly promoted in the local science curriculum seven years ago, the adoption and successes of the inquiry approach and nature of science has been uneven. Teachers are sometimes unsure or hesitant about the value of implementing some of these new pedagogies. This has been attributed to the prevalence of high stakes examinations. Unless teachers can be convinced that knowledge building helps in improving deep learning of science and development of science process skills, all of which are important conditions for excelling in the national science examination, teachers are not going to jump onto the bandwagon readily.

In this study, our goal is, therefore, to find out the knowledge development of a group of students as they participated in a Knowledge Building activity in environmental science. The research question we seek to answer in this study was how and what advancement in the knowledge of science (content knowledge, process skills and nature of science) was made as a group of elementary students participated in a Knowledge Building activity in Singapore.

Method

This study looks at the knowledge building process among a group of five Grade 4 students from a local primary school. They had earlier participated in the Nature Learning Camp (NLC) program, a project that was started by a group of nature enthusiasts to raise students' awareness and understanding about their environment. The program involves bringing students out for field trips to local nature reserves. Students would then identify and work on puzzling science problems about what they had experienced during the field trip. They could then decide and devise the relevant activities to conduct to help them solve their problem.

In this study, the five students went for a fieldtrip to a local rainforest where they made many observations. Upon returning, they were curious about the wide variety of trees there and wondered how they could survive. This led them to generate hypotheses on an online forum about what trees needed to survive. They met once a week for five weeks to work on their environmental problem with each session lasting 90 minutes. In the process, they worked on different ideas they had about what plants needed to survive and planned investigations to test their hypotheses. As they conducted the investigations, they were faced with more puzzling phenomena which led them to probe further into the phenomenon. At the end of the knowledge building process, the students shared their findings with other NLC members in a students' symposium.

Data sources for this study included video data of students' activities and artifacts created by the students (e.g. presentation slides). Using discourse analytic methods, the advancement of students' ideas in both disciplinary content knowledge and process skills were tracked. We found that there were some signs of advancement in scientific knowledge and process skills during the knowledge building process.

Findings

Advancement in process skills

Due to a difference between viewpoints about whether plants needed oxygen either in the day or night, the students decided to test out their hypotheses. As they shared their ideas on how the investigation could be carried out, they were encouraged to critique one another's ideas and help to refine them. One important idea in mastering science process skills is the need to set up a control experiment. The idea of control cropped up several times in the students' discussion, though not necessarily using the correct terminology.

In Excerpt 1, student NL initially suggested using one plant to find out if a plant needed oxygen at night. He then changed his mind in turn 198 when he realized that he had wanted one plant for the day (turn 208) and one plant for the night (turn 212).

Excerpt 1: Use one … or two?

Turn	Speaker	Content
188	Nai Liang	The day I think I only need one.
189	Miss Sim	You only need one?
190	Nai Liang	Yeah.
191	Miss Sim	Okay. How are you going to do with the one plant to plan this investigation?
192	Nai Liang	Uh I put the water and the fertiliser inside (.)
193	Miss Sim	For this plant?
194	Nai Liang	Yeah.
195	Miss Sim	Then?
196	Nai Liang	Then the: the second one I put it into a box first.
197	Miss Sim	But how many plants do you need?
198	Nai Liang	Two.
199	Miss Sim	Why do you need two?
200	Nai Liang	Just two
201	Miss Sim	Okay. Two plants
202	Nai Liang	Yeah
203	Miss Sim	One is
204	Nai Liang	At the:: put at the grass one.
205	Miss Sim	Okay. Grass?
206	Nai Liang	Um .The the
207	Teacher	Open space ah?
208	Nai Liang	Yeah op open space.

Turn	Speaker	Content
209	Miss Sim	Okay open space where they get (.) carbon dioxide, they get (.) water
210	Nai Liang	Yeah
211	Miss Sim	They get sunlight, they get fertiliser.
212	Nai Liang	Yeah. Then when it is night hor then hor uh:: the: you take the: plant uh: to the: one the box then we take the the other plant put it at the night one (.) then put the other plant (later) at the day we put it into a box first. Then we take out at night.

However, student YS disagreed and counter-suggest that one plant would be sufficient (see excerpt 2, turn 249) but merely explained that "if you have two plants … it's very hard to get an answer" (turn 253).

Excerpt 2: Need one plant

Turn	Speaker	Content
247	Ying Seng	((I just tell him we need)) we need only we only need um: we (.)
248	Miss Sim	Um.
249	Ying Seng	Need one plant
250	Miss Sim	We need one plant only?
251	Ying Seng	Uh yeah
252	Miss Sim	Why why do you say he needs one plant?
253	Ying Seng	Because, because he want in the day or in the night. Then if you have if you have two plants you want you want to put it in the

Turn	Speaker	Content
		day then you want to put it at night then you… (Looks up) But it's very hard to get an answer.

In excerpt 3, NL agreed with YS's suggestion that one plant was sufficient. He explained that "if the plant die that means the plant uh: don't need oxygen". However, when prompted by the teacher repeatedly (see turns 730, 742 and 744) if using one set-up was a fair test, NL changed his mind back to two.

Excerpt 3: Need one plant also can

Turn	Speaker	Content
725	Nai Liang	I think we only need one. Plant.(Points index finger in the air) But…
726	Miss Sim	One what? One plant? Then?
727	Mahmoodur	I think *this* is better. ((referring to the earlier plan using two plants))
728	Nai Liang	((Uh))
729	Nai Liang	Then uh:: uh I do my one so then we don't have to carry out the other experiment because when we put the we take out the already then we wait for a a day then if the plant die that means the plant uh: don't need the oxygen (.) So it means that uh: uh: (.2)
730	Miss Sim	Do you all agree with him? His only need one. So: you remove the remove the oxygen inside. So, the next day if you see the

Turn	Speaker	Content
		plant dies that means the plant does not need oxygen. Would you all agree with him? (.5) Would you all agree with him? If you all disagree tell him. We see how we can make the the experiment better because we are going to carry it out you know. So we are going to plan a fair test. Right or not? So for Nai Liang's one do you have any question if he uses only one plant?
		.
		.
		.
742	Miss Sim	So one one set-ups will it be fair?
743	Nai Liang	(.3)Uh:::
744	Miss Sim	What do you think?
745	Nai Liang	I think another one.

Following this series of conversation about the number of plants needed to ensure "fair" test, the other students also changed their plans to use two plants, with one acting as a control. Excerpt 4 shows student M externalizing the idea of control although the term was not explicitly used in the discourse. With the guidance from his teacher, he was able to articulate the design of the second set-up (control) (refer to turns 1009 – 1016).

Excerpt 4. And another one.

Turn	Speaker	Content
996	Miss Sim	So you need only one plant?
997	Mahmoodur	And another one.
998	Miss Sim	Oh. Another one okay.
999	Mahmoodur	((Draws another diagram – a square for 7 seconds))
1000	Miss Sim	So the first one without oxygen. The oxygen removed already. The second one?
1001	Mahmoodur	Eh. ((Draws wrongly and erases the board))(.4) Inside have uh: other air.
1002	Miss Sim	Does it have oxygen also?
1003	Mahmoodur	Yeah.((Continues to draw plant))
1004	Miss Sim	Okay. (.11) All right then?
1005	Mahmoodur	Uh:: This one uh: also need water
1006	Miss Sim	Oka:y. (.5)
1007	Nai Liang	Night one ah?
1008	Mahmoodur	Day. (Yes)
1009	Miss Sim	Okay. (.3) All right. (.2) So now look at this ah: Mahmoodur this one ((Writes on the initial diagram drawn by Mahmoodur)) no oxygen right? No oxy:gen. But (.) water?
1010	Mahmoodur	Water have.
1011	Miss Sim	((Continues writing on diagram)) Water ah:: There's water. But no oxygen. ((Goes to the second diagram drawn)) This one?
1012	Mahmoodur	Uh: this uh: have oxygen.

Turn	Speaker	Content
1013	Miss Sim	Oxygen. ((Writes 'oxygen' on second diagram)) Okay. What else?
1014	Mahmoodur	And other gas.
1015	Miss Sim	All right. Any water?
1016	Mahmoodur	Yeah have.

In short, there was refinement in the students' process skills, particularly in the idea of control in science experimental designs. However, there was lots of facilitation by the teacher needed to direct their attention to salient features or issues related to designing an investigation.

Advancement in Content Knowledge

As the students carried out their investigation, unexpected results puzzled them, hence triggering inquiry into the phenomena observed. In such instance, students were puzzled by an anomalous result they obtained when investigating whether plants needed oxygen to survive in the dark. They removed oxygen from a tank by burning a candle in it, thinking that all the oxygen in an enclosed tank would be used up when a burning candle was extinguished. With a plant placed in a tank "without" oxygen and another in a tank "with" oxygen, and placing them in the dark, they made observations of the plants every day for a week. After one week, they found that the plant in the tank "without" oxygen was growing better than the plant "with" oxygen. They were puzzled by their findings and went about trying to find out the reason.

After some discussion, they proposed a number of hypotheses. Table 1 shows their hypotheses put forth.

Table 1. Hypotheses explaining why plant "without" oxygen grew better than plant "with" oxygen.

Hypothesis	Students
I. "too much water to … the plant in set up A" because "water vapour is more … at set up A"	by YS and M
II. "gaps might not have been sealed properly" so air "can go through"	by NL and HL
III. "In fact have we really got rid of oxygen?"	by YS (revoiced by teacher)

They thus sought the help of Dr L, a biologist in the NLC program to help explain their observations. Dr L directed them to think about whether "when we burn the candle, do you think the candle will use all the oxygen?" With some help from Dr L, they found hypothesis III to be the most plausible. Therefore they decided to repeat the experiment by removing air completely from the tank using a vacuum pump instead.

With some help from Dr L in terms of getting the appropriate apparatus for the investigation, they repeated their investigation, but this time, all the air in the tank was removed using a vacuum pump. But a few days later, they found water droplets below the plant pots. This wondered where the water droplets came from. They hypothesized "perhaps there was a leakage of air somewhere" (Hypothesis II in Table 1). Thus they redid the experiment on their own. However, water droplets were still found in the tank the next day. This time, their attention turned to the clips. They used the strongest clip they could find, but to no avail. They even sealed the base of the tank with Vaseline. They were dismayed to find water droplets in the tank still. NL reported to Dr L that "you see we fail". However, with some authoritative information from Dr L, who explained that "the plant opens its stomata and some water vapor comes out". They thus came to realize that the water vapour could possibly be a result of transpiration of plants. In the final presentation of their knowledge building progress, they reported that one of the things "we have learnt from carrying out the experiments" was "water vapour can escape from the plant through the stomata".

In short, we found modest advancement in students' understanding about the process of combustion and plant processes. First, they come to realize that although combustion needs oxygen, it will not use all the oxygen in the tank for combustion. Second, they learnt about the process of transpiration. Although these advancements might seem insignificant, they were made through sharing of ideas, negotiation with one another and consultation with experts. They represented the first steps of these students as they attempted to participate in building knowledge as a community.

Understanding of NOS

At the end of the KB activity, the students were interviewed for their views about science. They were asked (1) what science means to them and (2) in what ways they had behaved like a scientist during the KB activity. Table 2 shows the answers from the students.

Table 2. Students' responses to interview questions.

Question 1	**Question 2**
Test out something to see is it true or not, … if not true, continue repeating the experiment … because doing the experiment one time does not mean you'll get the thing correct (YS)	They need to have confusion first before they have answer. We need to predict before we test them out. (YS)

Question 1	Question 2
Improve old idea to new idea so that we need to keep testing it … to get a reliable data … science has no true or false … some science we still don't know the answer and we need to test them out. What we know can change if technology is better. (NL)	Think crazy (NL)
-	Logical thinking … they think from illogical to logical … others help them and then they carry out ((experiments)) … find out themselves (HL)
-	Sometimes give suggestions which has no right or wrong answers but got to test them out one by one (MH)

The responses given by the students in Table 1 shows that some of their ideas were consistent with current understanding of the nature of science. For example, NL saw that in science, it is possible to "improve old idea to new" but need "reliable data" to support them. He also saw the role of technology in this knowledge creation enterprise. They also saw the creative side of science as NL thought of scientists as those who "think crazy" or like the way HL put it, "think from illogical to logical". HL's perception of science is both a social and individual activity as she described that in scientific practice, "others help them and then they carryout ((experiments)) … find out themselves". However, there was also the perception that science experiments were meant to "get the thing correct" as put forth by YS.

Discussion and Conclusion

The findings of this study show that when the focus of inquiry activity is turned towards refinement of ideas, learning surpasses beyond the answers that the task set. In this case study, the five students set out to find out whether plants needed oxygen at night. However, the new ideas they had constructed went beyond the answer to the task. Besides finding out the answer to their question, their ideas about process skills were deepened, especially about the use of control in experiments. They had also come to understand plant processes (transpiration) better as they went about trying to explain for the presence of water vapour in the tank where all gases were supposedly pumped out. In participating in the process of knowledge building, they also develop some ideas about what science is about.

However, we found that there were challenges in trying to get these students to do knowledge building. As can be observed from the excerpts above, there was a lot of reliance on the teacher to facilitate the students' discussion. We noticed that students often were side-tracked as they discussed. They also couldn't remember what they had discussed earlier. They had to be constantly reminded by their teacher what they had discussed or be directed back on track to their discussion topic. Such challenges pose difficulties to KB implementation in larger science classrooms due to insufficient number of teachers to facilitate group discussions.

Another problem observed in this case study was that the students' talk was somewhat shallow. For example, they were often not able to provide a good justification to their claims (e.g., Excerpt 2 turn 253). A good collaborative inquiry requires students to be able to persuade, negotiate, deliberate and seek information (Walton, 2000). Scaffolding is therefore needed to assist students in putting forth a good argument. Scaffolds could be in the form of sentence openers (e.g., theory scaffolds in Knowledge Forum) or using argumentative scripts (Kolodner, 2007).

In a nutshell, Knowledge Building approach puts ideas at the center. The learning outcome from a KB approach surpasses beyond merely knowledge acquisition. It develops the spirit and skills of knowledge creation in students. However, the process of knowledge creation is not an easy one. Scaffolding strategies are needed to support these students in the process of knowledge building. Technology can play an important role in the process. These findings are important to the study as they inform us of the types of intervention needed in our next cycle of design research.

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