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Knowledge Building in Elementary Science

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Richard Messina and Richard Reeve describe a three-year study of applying the principles of knowledge building and using the Knowledge Forum® software in a Grade 4 science class. They report on the success of the project in the final year in establishing a knowledge-building classroom community.

1. How could elementary teachers apply these principles in their classrooms?
2. Are there obstacles to using these teaching methods?
3. How could this structure be applied without access to the specific computer software?

The educational innovation of knowledge building refers to the construction of knowledge that is of value to a community (Scardamalia, 2000). In schools, knowledge building typically takes the form of a class of students building knowledge together around a shared problem of understanding. In their ideal form,

knowledge-building classrooms have been likened to scientific research teams (Scardamalia & Bereiter, 1999). Scardamalia and Bereiter have indicated that to make the transition to a knowledge-building community requires a dramatic shift from an incidental focus on learning activities to a focus on the construction of collective knowledge (Scardamalia & Bereiter, 1999). As a result, knowledge building is not simply another approach to learning but is instead a new way of conceiving of the goal of education (Scardamalia, 2001). To make the shift to a knowledge-building community, teachers must progress from how they previously functioned as teachers to how they envision they need to function to make knowledge building a success in their classroom (Reeve, 2001).

This chapter reports on the design iterations that were implemented over a three-year period as three successive classes of Grade 4 students built knowledge about the concepts associated with the study of light. The research study took place at the Institute of Child Study Laboratory School at OISE/UT. Below we highlight key design features associated with the incremental shift toward a knowledge-building community, along with the improved conceptual understandings of the successive groups of students.

USING KNOWLEDGE FORUM®

In all three years, the communal software environment known as Knowledge Forum® was used to support the knowledge-building work of the classes. Knowledge Forum® is a networked database in which students create text notes on a problem they are investigating. It provides a medium for preserving questions and ideas in notes that are continually available for further discussion and revision. Other members of the class may "build-on" if they have information to add to the original note or are seeking clarification. Only the author of each note can modify/revise his or her own notes, but all notes are visible to everyone. Students are encouraged to state the problem they are addressing and to highlight the important vocabulary in their note. The identification of key words helps others find the note when a search by key words is conducted. Scaffolds are also available to help support and define the kind of writing and thinking that is being done in the note. For example, the Theory Building scaffold includes the following supports: My Theory, I Need to Understand, Evidence, A Better Theory, New Information, and Putting Our Knowledge Together. Authors can also create pictures and diagrams within their notes. Once titled and contributed, the note is automatically displayed in the view in which it was created. Views are spaces within the database where groups of notes can be arranged. Views are titled and may contain a background illustration created by the students to help organize the notes. Links from one view to the others can be placed throughout the database. Notes that deal with similar problems or investigations may be collected and placed within a new note called a rise-above. In rise-above notes, students summarize and organize the knowledge recorded in the collected notes, thereby representing a collective group understanding.

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Year 1—Specialization

In the first year, the students were placed in groups based on their interests. Each group knew what its members already knew, had a sense of what they wanted to know, designed and conducted experiments to research their theories, and participated in reading groups with the other members of their group, using readings they often brought in themselves. However, students felt ownership only in their area of study. There were three essential components for the students:

1. Time to research/gather information
2. Opportunities for discovery through research and experimentation
3. Time on the computers to record findings and further questions that would be shared with the rest of the class

As there were 22 students and seven computers in the class, it made sense in the early stages of the study to divide the class into three random groups. The three-part cycle was created, consisting of 40-minute sessions, two to three knowledge-building cycles per week.

In previous implementations of knowledge building, it has been found that children's questions exceed the complexity of material available for their grade level (Messina, 2001; Reeve & Lamon, 1998). Therefore, an adapted version of reciprocal teaching (Brown & Campione, 1996) was introduced to the class to be used as a tool for groups to enhance their comprehension of important material that may be too difficult to understand without the support of other group members. In these groups, a leader would ask questions to clarify the core content of the material read. The group would decide what information was important and understood. These points were recorded as dot-jot notes. Each student was given a black lab book (research journal) to record his or her notes.

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The experiment/exploration portion of the cycle was designed to support and promote the students' curiosity and questioning. Experiments were conducted on a designated table in the classroom. Often the students were asked to follow planned steps (teacher-designed experiments) and record the data in their research journals. The experiments were conducted by the students and were designed to complement the readings being done during reciprocal teaching. The students could be heard at the experiment table using the new vocabulary they had learned in their readings.

The cycle was made complete with time on the computers using Knowledge Forum®. This was the opportunity for the group members to state their research problem, offer their theories, and record their attempts to improve on their conjectures by writing the knowledge advances they experienced from experiments and readings. Because satisfying answers to their problems were often unattainable, new questions were added to the database, and the inquiry process would continue.

Within the database, students were expected to keep a note in their portfolio about their complete understanding of light. Based on the growth of these portfolio notes, it was clear that although they were being intentional learners, they were not acting as members in a knowledge-building community. The students were writing only about their own area of research. Students were exposed to the findings of other

groups during knowledge-building talks, simply by being in the same environment while a group was conducting an experiment, yet they did not feel comfortable writing about any of the other concepts of light that they themselves had not investigated.

Again, the focus of this design study was to create a knowledge-building community. The first year can clearly be identified as a transition from a focus on intentional learners, organized into interest-based groups, to a whole group with a collaborative knowledge-building focus. Clearly each specialized group felt ownership of its aspect of the study of light, but there was little demonstration of view interrelationship. The community did not share the responsibility for the overall advancement of knowledge. This became the impetus for the following year's redesign.

Year 2—Sharing Knowledge

The groups in the second year organized their views in ways that brought order to their knowledge.

In the second year, the students organized themselves into six groups based on their interests. Although each group was in charge of a view in the database, the students were continuously encouraged to read and build onto notes in all of the views in the database. The goal was for the students to develop a breadth of understanding about the concepts associated with light. Data from pre- and posttesting and the students' portfolio notes about their understanding of light both indicate significant gains over the first-year group and suggest this strategy was successful.

It is believed that the creation of the class mission statement and frequent knowledge-building talks on the importance of developing a breadth of understanding of each other's views helped to create this dynamic. In addition, the community needed to approve the research interests of each group to ensure they were aligned with the overall class mission. Students were encouraged to see that sharing problems and knowledge was to advance understanding beyond the level of any one individual, that collective understanding surpasses the most knowledgeable individual. Situations where deeper understanding was created through the work of students working across views were highlighted and celebrated to encourage more cross-view interaction.

With students reading and contributing to all views while specializing in one area, the teacher felt that special attention needed to be paid to the principle of improvable ideas. The metaphor of a ball of clay to represent a theory during a knowledge-building talk was an attempt to prevent students from becoming emotionally attached to their theories, that is, to create a psychologically safe culture. Students needed to be comfortable receiving and giving criticism about theories on the database and during knowledge-building talks. It was stressed that the discourse needed to be about the advancement of knowledge. This empowered the students to think that the current accepted theories in science were simply the ones with the best supporting evidence but that there were many other, perhaps better theories that had yet to

IMPLICATIONS FOR TEACHING

The knowledge-building classroom takes on characteristics of the scientific community . . .

1. Experiment and explore to support and promote curiosity and questioning
2. Bring order to knowledge
3. Develop a breadth of understanding about the concepts under study
4. Discuss and review results

be supported with evidence. The students felt that they themselves might, through their own work, be able to prove the next new theory.

The groups in the second year organized their views in ways that brought order to their knowledge. Some wrote paragraphs in the background of their views, helping the other members of the knowledge-building community to navigate each view. Rise-aboves were created to achieve new syntheses and were used to notify members of other views about what the "big ideas" of each view were. Thus the children were creating their own curriculum, describing for themselves the key concepts in each view. Students used these notes in writing their portfolio notes. A review of the content of these notes suggests that the Grade 4 class identified problems and knowledge that were beyond those that are normally engaged in at Grade 4.

Year 3—Knowledge-Building Community

In the third year, the goal was to advance the classroom design in such a manner that the students would be building knowledge collaboratively, not just sharing it between views. Rather than have students decide on a focus for their study of light and commit to that area, the attempt was made to create an environment that was much more organic, fluid, and generative. Thus, although students demonstrated an interest in a particular area of light, no discrete groups were formed around those interests. Instead, views were created in the Knowledge Forum® database, and students were encouraged to work in any and all of the research views in the database.

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Specific focus was placed on the knowledge-building principle of epistemic agency (Scardamalia, 2000). In the past two years, the teacher had previously decided the content of the year and creatively positioned the concepts so as to create the impression that the children were initiating the inquiry based on their interests. However, this year the teacher consciously avoided directing the learning and therefore did not impose a structure by directing the learning. Instead, as students began to work in the various database views and in their portfolio notes, the idea of "view masters" was created where groups of students adopted a view, read all the notes, and recorded the big ideas in the background of the view. This process seemed to encourage others to work on reciprocal teachings, to gather information, and thereby to support the knowledge building occurring in the weaker views. What evolved was a whole class working as a single research group with multiple subgoals under- and overarching the mission of being a knowledge-building community. Results from pre- and posttesting of the concepts associated with light also indicate that this third year was the most productive year in terms of both depth and breadth of coverage.

Surprising Results!

Over the span of this three-year study, several database analyses were performed along with pre- and posttesting of the children's understanding of light concepts. The results suggest strongly that the technique of not assigning views in the third year led to the most productive knowledge-building community of the three years. It is compelling to note that in the third year, the students read extensively across the database views (82%), had significant improvements in their understanding of light

($p < .0009$ on 12 of 18 questions), produced the most notes per student, and worked on more problems than in the previous two years.

These results were surprising to the classroom teacher. Prior to receiving the data, the teacher indicated he felt the unstructured approach in the third year may have been developmentally too advanced for Grade 4 students. His theory was that the second year represented the ideal structure for knowledge building to proceed. Again, the design for the second year was small groups who were focused on a specialization, embedded in a larger community with the goal of sharing knowledge between groups. The teacher's previous experience suggested to him that children require tight arrangements of separate groups to make significant advances. In these arrangements, students are organized on the basis of interest, academic ability, and social or emotional needs. None of these factors were taken into consideration in the design of the third year. Also, in the first two years, it was a typical practice to identify clear goals for each of the groups with the belief that this would sustain the focus and contribute to internal group collaboration. The structural elements of knowledge-building talks, reciprocal teaching, student-designed experiments, and the use of the Knowledge Forum® database were present in all three years. However, in the third year, the students became a knowledge-building community through heightened agency over the processes by which knowledge was being created in their community. As a knowledge-building community, they created groups on a daily basis, made decisions about which problems of understanding required attention, and in turn produced knowledge that matched the breadth of the curriculum and exceeded its depth. But most important, as a knowledge-building community, they learned to produce knowledge of value to others.