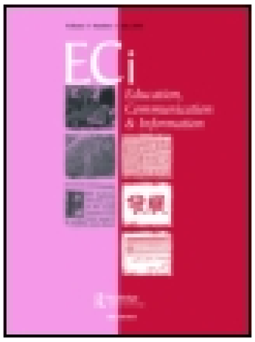

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Knowledge Forum: altering the relationship between students and scientific knowledge

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ABSTRACT *This paper explores the use of Knowledge Forum, a networked computer program designed to support knowledge building communication and to foster thinking and learning skills. The paper focuses on a Grade 5/6 classroom and looks at how students view scientific knowledge and what it means to learn science. A shift in pedagogy, along with the learning opportunities afforded by the communal database, impacted the learning environment and created changes in the structure of the learning activities, the 'rules of the game' of science and the sequencing of the curriculum. Specifically, the paper examines the knowledge transforming discourse that occurred both on and off the database as children worked to understand the evolution of the Komodo Dragon during an investigation of islands and island biogeography.*

> *'Why should I bother writing down my theories, when in a hundred years, they will be wrong?'*
> *'Well, think about it. If Alfred Wallace hadn't written down his theories, where would we be today? Charles Darwin likely wouldn't have had the nerve to publish his ideas.'*
>
> *'Even if you learn something perfectly, or are a pioneer in your area, all your work is useless if nobody else can understand you. You might as well have done no work at all. The point of learning is to share it with others. Lone learning is not enough. When you experiment, always keep notes, including notes on how you did your experiment, so that other people can try your experiment. If you find something*

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> *interesting that is outside your area of research, but somebody else could use, alert them to it. Otherwise, they might not make an important learning advance, and who knows, maybe you might suffer? All in all, learning is INCREDIBLY important, but how you learn is even more so.'*

What does it mean *to learn science*? How do students view *scientific knowledge*? David Cohen (1988) warns that the view of science knowledge as a fixed entity, as 'factual, objective, and independent of human distortion' is part of our scholastic inheritance. What if, instead, learners came to see the current state of knowledge in the sciences as tentative, as progressing through continual refinement and problem redefinition? What if students came to understand the purpose and power of replicability for building knowledge in the sciences, as opposed to carrying out and repeating experiments as part of schoolwork required to satisfy the teacher. Such a shift in students' perspectives on scientific knowledge is critical. As Scardamalia & Bereiter (1989) point out:

> *In the learned professions growth in knowledge is a requirement. Participants see themselves as contributors to knowledge, and as such they must continually monitor information for how it can advance their understanding and how they, in turn, can contribute to its advancement. The major challenge of schooling according to this view is to get students involved in the active pursuit of understanding and to see themselves as contributors to knowledge. (p. 10)*

The quotations from students at the beginning of this article highlight the possibility of developing such relationships between young learners and scientific knowledge. Not only do the students raise the idea of scientific knowledge as tentative, and point to the importance of key scientific notions such as refinement and replicability, they also begin to look critically at their own role in building scientific knowledge: Can I make a scientific theory? So what if I do? In addition, the students raise issues concerning the very nature of learning itself. They define learning as being understood by others, and place high value on being able to contribute one's learning to an evolving communal understanding.

The reader might be surprised to find that the students making the opening comments of this paper are 9, 10 and 11 year-olds working on a science unit in their combined fifth and sixth grade classroom. This article focuses on a particular science unit, and follows the course of a teacher's changing view on pedagogy along with her students' developing views of scientific knowledge and of themselves as learners. We examine the ways in which the discourse of the classroom is supported through the use of Knowledge Forum, a computer-supported collaborative learning environment. The focus in the classroom is on knowledge-building activities—ways students can work with ideas and with each other to deepen their understanding in a particular area of inquiry. The goal is for the classroom discourse to become the kind that takes place in the disciplines when scientists are trying to work out theories and solve problems. Such 'knowledge transforming discourse' (Bereiter & Scardamalia, 1993) is central to knowledge building, and can be found in the interactions both offline and online in Knowledge Forum in the classroom we examine.

Shifting Pedagogy

As a teacher, the first author has experienced a shift in her view of learning and teaching science. Science had always been presented as a domain that is primarily fact-, theory- and concept-based. So the role of a science educator, she thought, was to give this knowledge to children. Caswell's idea of teaching science was to provide a number of attention-grabbing experiments and have students fill in worksheets in order to explain the phenomenon they had just witnessed. Science time also meant activity centers, where students moved from station to station (usually as quickly as they could), trying out expert-designed experiments, reading teacher-selected resources, and filling in the checklist as each station was completed.

Setting up science stations for hands-on experiments did seem like a pedagogical advance over her own science teachers, different from their dry lectures and presentation of science as a subject involving the memorization of facts. Still, there was always the perplexing dilemma as to why the students did not seem to be exhibiting the same enthusiasm for these centers as was the teacher who created them.

In 1996, Caswell was introduced to a new approach to science education. Just at the time that she was seriously examining her own classroom practice and striving for higher educational goals in the teaching of science, she had the opportunity to attend a science workshop run by a group of socio-cognitive and educational researchers from the University of Toronto. These researchers were committed to designing learning environments that supported a culture of scientific inquiry in elementary school classrooms. The workshop featured the use of technology to support a knowledge-building pedagogy. The technology was at that time called CSILE (Computer-Supported Intentional Learning Environment), and its design and development was based on research in reading, writing and the nature of expertise (Scardamalia *et al*., 1989; Bereiter & Scardamalia, 1993). The purpose of the research was to try to define the cognitive processes that were going on in the minds of experts and to make these processes visible and available to students.

In the course of working with these researchers, Caswell began to reflect on her own classroom: 'Students in my classroom are talking, but what is the quality of their discussions? Are ideas at the center of what their discourse is about? What about the struggle between allowing student ideas and discourse as the central driving force of the curriculum and the notion that there are right theories in science that have to be taught?'

Over the past several years, Caswell's pedagogy has been evolving. This change can be characterized as a shift from activity centers to students forming research groups according to common interests; from teacher-designed experiments to student-designed experiments; from the gathering of resources by teacher only to collection by both teacher and students. The focus of classroom work and discussion revolves around trying to gain a deep understanding of a unit of study. Students work collaboratively and independently to gain understanding of materials, and to improve ideas. Their dialogue ranges from face-to-face whole group discussions, to small group research team meetings, to reflective discourse within the database. The teacher's goal is to create a classroom environment where genuine productive work can take place and where students are immersed in a culture of inquiry.

Knowledge Forum as a Catalyst for Change

The CSILE software has developed over the years into a learning environment called Knowledge Forum. Knowledge Forum allows learners to construct a communal knowledge base, and serves as a discourse medium where learners can discuss the knowledge that is being constructed. Typically, students investigate problems in different subject areas over a period of weeks or months. As students work, they enter their ideas and research findings as notes in the Knowledge Forum database. Contributions to the evolving communal knowledge base can take many forms, including (a) *individual notes*, in which students state problems, advance initial theories, summarize what needs to be understood in order to progress on a problem or to improve their theories, provide a drawing or diagram, etc., (b) *views*, in which students or teachers create graphical organizations of related notes, (c) *build-ons*, which allow students to connect new notes to existing notes, and (d) *'Rise Above' notes*, which synthesize notes in the knowledge base.

Any of these kinds of contributions can be jointly authored. The environment supports students in constructing their notes through features such as theory-building scaffolds (e.g. 'My Theory,' 'I Need to Understand'). Students can read through the knowledge base, adding text, graphics, questions, links to other notes, and comments on each other's work (see Fig. 1).

One aspect of Knowledge Forum critical to the shift in pedagogy is that it involves much more than software. It is a philosophy. The environment involves a new model of learning (Bereiter, in press) that Scardamalia & Bereiter (1996a, b, 1999) call 'Knowledge-Building Communities.' Of course, Knowledge Forum can be used in classrooms that may or may not have adopted the pedagogical model. However, the essential idea is that students work together to make sense of the world around them and work towards advancing their own state of knowledge and that of the class. The

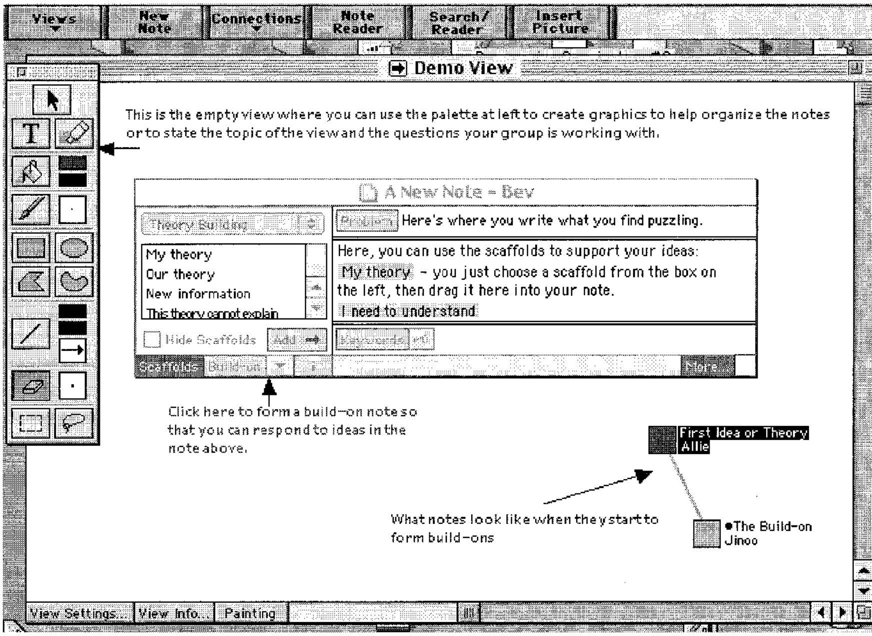

FIG. 1. The basic, beginning features of Knowledge Forum.

goal is to engage students in progressive knowledge building, where they continually develop their understanding through problem identification, research, and community discourse. The emphasis is on progress toward collective goals of understanding, not simply individual learning and performance.

The classroom investigations discussed in this article were carried out in a Grade 5/6 classroom during the fall term (1999) at the Institute of Child Study, a laboratory school affiliated with the Ontario Institute for Studies in Education at the University of Toronto. The daily participants included 22 students (9–11 years of age), a classroom teacher (Caswell), and a graduate student teacher candidate (Randall). Consultants included a teacher-researcher (Reeve) and a university researcher (Lamon). It is important to note that the students in this classroom had used Knowledge Forum for 2–3 consecutive years and had become familiar with the concept of 'knowledge building,' as well as with the use of the software and the Internet. The teacher, teacher-researcher and researcher each had experience with the software for at least 4 years. The classroom case study described here focuses on a 3-month investigation conducted by students (along with their teacher and student teacher) struggling to understand the principles of evolution during a unit on 'Islands and Island Biogeography.'

A Shift in the Learning Environment Created in the Classroom

The shift in Caswell's pedagogy, along with the learning opportunities afforded by the communal knowledge base, impacted on the learning environment created in the classroom. Overall, there was a move toward more open exchanges, deeper inquiry, and a more flexible, student-driven research agenda resulting from changes in the structure of the learning activities, the 'rules of the game' of science and the sequencing of the curriculum.

The Structure of the Learning Activities: multiple approaches to inquiry

Typical knowledge-building classrooms are abuzz with the business of inquiry. They are not just about discourse or working online in the database. Students form research teams according to common interests within a given unit of study and are immersed in a culture of inquiry. Knowledge Forum classrooms usually involve a wide variety of learning activities, although different teachers tend to develop different repertoires (see Lamon *et al.*, 1996; Hewitt, 1998; Bielaczyc, 2001).

In Caswell's classroom, students spend at least 1 hour each morning in Inquiry Time, which consists (depending on need) of a variety of classroom structures. The classroom was equipped with six networked computers. Given a class of 22 students, Caswell addressed the computer–student ratio by dividing students into subgroups during Inquiry Time. Typically, for the first half hour, six students work independently on Knowledge Forum (reading or creating notes), while six students read with the teacher in a guided reading session (e.g. Reciprocal Teaching); five students test/design an experiment while the remaining five students do independent research. After half an hour, students switch.

There is a fine balance between student independence and teacher structure: after a few years, it is easy to read the signs when a unit is nearing an end or needs a boost or needs to be revisited from an entirely different angle (sometimes this is more for the teacher's sake than for the students). Caswell integrates a variety of offline learning activities meant to support student inquiry, such as independent research with library or Internet resources, designing and testing experiments, building models, going on field trips, presenting work, guest speakers, and creating and performing science skits or songs. She also found that many of the participant structures for Fostering Communities of Learners (FCL), a classroom innovation focused on developing a community of inquiry (Brown & Campione, 1994, 1996), could be integrated with knowledge building pedagogy and the use of Knowledge Forum. These participant structures include the following.

- *Benchmark Lessons.* A benchmark lesson is a teacher-led whole class activity designed to instigate conceptual change in students (diSessa & Minstrell, 1995). It can be an experiment that the teacher demonstrates to the class, or it can be as simple as showing a stimulating 5-minute video segment followed by a class discussion. It should present a dilemma and stimulate a response from the students.

- *Reciprocal Teaching Sessions*. Reciprocal teaching is a reading comprehension technique developed by Brown & Palinscar (1989) that involves groups of students reading a particular resource, then questioning, summarizing and opportunistically clarifying and predicting.
- *Crosstalk*. A 'crosstalk' (Brown & Campione, 1996) is a democratic, whole class discussion where students present their emerging research ideas. This usually takes place in the form of the class (including teacher) sitting in a circle on the carpet so that everyone can be seen. One person starts the discussion with a problem or dilemma of understanding then 'hands off' to another class member who has indicated (by raising a hand) interest in adding a 'build-on' to that idea. Rules of respect are that you don't raise your hand until someone is finished speaking. In Caswell's class, students 'hand off' in a boy–girl pattern to avoid boys inevitably handing off to boys and girls to girls. At least once a week, a crosstalk session is used to hear students' important questions and to reveal areas of confusion that a benchmark lesson might clear up. The classroom discussions (e.g. crosstalk) reinforce the democratic approach to knowledge building and lay the foundation that ideas are to be respected. Often, you can see in a crosstalk certain students who were adamantly opposed to an idea come around and say, 'Hmm, I hadn't looked at it that way' or 'I'll have to think about that.' Or, they remain adamantly opposed and sufficiently motivated to gather new data or resources to support their claims.

Students in Caswell's class use hard-covered, inexpensive science 'lab' books to support the authentic work they are doing. Students are told that the books are similar to Darwin's field journal, a place to store ideas and questions that may arise during their studies.

Most Inquiry Time periods have a wrap-up session where groups report on problems they are working on. In this way, students understand the value placed on the learning that has taken place that day.

New Rules for the Game of Science: challenging the 'scholastic inheritance'

The simple act of telling the students what is at the core of this new approach to inquiry—'Here's what we're going to be doing this year during Inquiry Time and here's some of the ways we're going to approach it'—sets the tone for the school year. What is amazing is that when, from the beginning of the school year, it is emphasized that everyone has ideas and ideas can always be improved, and science is a matter of discussing, testing and reworking these ideas, there is a kind of relief in the faces of the children. It is almost as if they are thinking, 'finally someone is letting us in on the rules of the game of science.'

The theoretical framework of knowledge building is introduced to the children almost as a new game in gym would be introduced. Quite simply, students sit on the carpet in a circle during that first science period and the teacher begins by saying that doing good science is all about working with ideas:

> *Ideas are pretty neat things. We've all got ideas and the thing about ideas is that they can be improved. They can always become better. Sometimes just the act of talking about ideas or tossing ideas around can improve them. For example, Allie, you might have an idea about the way an island is formed, and Jinoo might say, 'Well I never thought about it like that.' Or he might say, 'Have you ever thought about this?' Good science making is all about working with ideas, testing them out in different conditions, retesting, talking with people who are working on similar ideas, and bringing ideas to the whole group.*

Next, the computer software is introduced: 'We are lucky in our classroom this year to be able to use a new computer program that's been designed to help us with our "knowledge building" approach to scientific inquiry.' At this point, students are shown a poster displaying some of the unique features of Knowledge Forum:

> *It is called Knowledge Forum and what's really unique about KF is that our class gets to create its own database. Each of you can write down your ideas in your own notes, but what's really cool is that everyone else in the class, no matter which computer they are using, will get to see each other's notes appear on the screen.*
>
> *No one else can go into your note and change anything because you have your own password, but the cool thing is that people can 'build-on' to your ideas by clicking on a special build-on button at the bottom of each note. So if Jinoo is talking about an island that's been formed by volcanoes and Allie has some information that she's just read and would like to give him, she can just click the build-on button and use the special Scaffold that says 'New Information,' then type in the information. Once Allie titles her note, it gets joined to Jinoo's note like a web. In this way, our class can begin to build knowledge about certain units of study. Knowledge building is a new approach to teaching that's being used in countries all around the world and we're going to start using it today.*

This introduction to the concept of knowledge building has had the same effect on each group of students Caswell has taught over the past 5 years. They immediately 'get it' and want to get started. Knowledge Forum gives students a framework, a discourse and scaffolds within which to develop that discourse and associated inquiry. It provides an outlet for a reflective, progressive discussion. For many students, it is the first opportunity they have had to make public their ideas and to begin to think about thinking.

Determining the Curriculum Sequence: the progressive curriculum

To kickoff the 'Islands and Island Biogeography' inquiry, Lamon and Caswell introduce the island theme during a class discussion asking what the children know about islands and how islands might be formed. One of the student exchanges included:

> *'I think, well, this is just a hypothesis, but I think, I think that, um, maybe when the tide becomes lower, then more sand can build up then also when the waves come over and also when volcanoes erupt that just makes one big island, depending on what's there, how big the waves are and how low the tide is.'*
> *'OK, I think that, um all the possibilities are correct and also, um as the earth shifts and land shifts maybe when there's, the earth moves, there's an earthquake and it splits. Water somehow goes in and forms a little island.'*
> *'There is no water under land.'*
> *'But you know how, when, OK, I remember when I was 5, when I used to try to dig to China with kids in my class and we would dig in the sandbox and it would get really, really muddy, and kind of like ...'*
> *'Moist.'*
> *'Water. Moist, but if it went down deep enough, you'd probably reach water.'*

Following this discussion, the group was subdivided into groups of four students (a boy and girl from Grade 6 matched with a girl and boy from Grade 5—to initiate community building within the classroom) and provided with materials (bins, slabs of rock, stones, gravel, water and sand) to work on building an island based on the group's common theory of island formation.

After students built initial islands, they worked in teams to co-author notes in Knowledge Forum using text and graphics to answer the question, *How are islands formed?* Three fairly distinct theories were put forward, and notes could be grouped as follows: (1) Volcano Theory, (2) Earthquake Theory, and (3) Water and Wind Push Theory. A fourth theory, 'coral growth,' was not present in the initial notes, but was subsequently considered as another possibility by the class. Students worked in research teams for 2 weeks to study one of the four types of islands. After this time, each group presented their research to the class through a tour of their work on Knowledge Forum, as well as presenting a song or skit to reflect their understanding (see Fig. 2, for example).

Students began to wonder about the flora and fauna of islands and how species came to islands. The story of Darwin and Wallace was introduced

(to the tune of Octopus' Garden by Richard Starkey)

Volcanic Islands
I'd like to be on top of the sea
With a volcanologist and me
I'm born form the sea, with magma inside me
Until lava erupts free for all to see!
Under the sea where the hotspots be
And the fiery mantle to see

CORAL ATOLLS
I'd like to be under the sea
With a big pile of rocks next to me.
A reef would grow around a volcano
The sea would rise up to the skies
I'm a coral atoll
To grow is my goal
There's coral underground
And colourful fish all around.

FIG. 2. An example of students' songs related to how islands are formed.

to the students in the form of a dramatic presentation by the teacher and student teacher (using narrative, visuals, readings from original journals, and brief video clips of the Galapagos flora and fauna). Students then re-enacted scenes and worked through the sequence of events in the lives of these historical figures [1]. During the presentation, the relationship between great thinkers and 'improvable' ideas was emphasized to students as well as the courage it takes to make public an idea that is not socially acceptable. Scardamalia (2000; in press) points out that 'discourse geared to knowledge creation' plays a central role in a knowledge-building classroom and models the scientific community as a 'prototypic example of an organization turned to knowledge transforming discourse.'

The teacher then provided a list of islands and a structure for writing a proposal to study a particular island. Students were challenged to write proposals to a ship's captain (imagining how Darwin may have been chosen for the voyage of *The Beagle*), giving reasons for wishing to join the expedition and listing what contributions would be made to the scientific community upon their return. Students provided strong reasons for wishing to join an expedition ('it's been a lifelong dream!' or 'I've already begun research on that island') and proposed that they would prepare museum displays or write books or go on speaking tours upon their return. The teacher read the proposals and grouped students accordingly. The class came up with a mission statement which included:

—to make sure you know all you can/you are interested in about islands;
—to study the origin and then the growth of your island;
—to understand everyone's island, all the different kinds;
—to get a deep understanding of islands;
—to push ourselves to the greatest level of knowledge we can.

Students did much of their work on Knowledge Forum during this part of the unit and eventually each group produced a comprehensive report about their island based mainly on their notes from the database. Parents were invited for the 'publishing' of the island reports.

Over the course of 3 months, student inquiry progressed through a variety of topics, starting with how islands are formed and moving into the study of endemic species, the story of Darwin and Wallace, theories of evolution, adaptation and survival, the study of specific islands, exploring the question of what makes a species, looking at cells, genes, Mendel, systems of the human body and, finally, the Human Genome Project. We did not travel through this order of study because it was from a curriculum guide, but because the students started pushing their own knowledge forward, forging into these new areas of study. In a knowledge-building classroom, student investigations within the unit of study are what moves the curriculum forward. The research team refers to this as a 'progressive curriculum.' Fig. 3 shows the Welcome View of the Grade 5/6 database and the inquiry topics studied by the end of the school year.

An interesting side note to this notion of a progressive curriculum is that the study of islands led students on a similar pathway of study to that of Darwin. Darwin was a geologist first, then an avid naturalist who delighted in studying the flora and fauna of his world. It was Darwin's knowledge of how the islands of the Galapagos archipelago were formed and the endemic species he discovered there that would lay the foundation

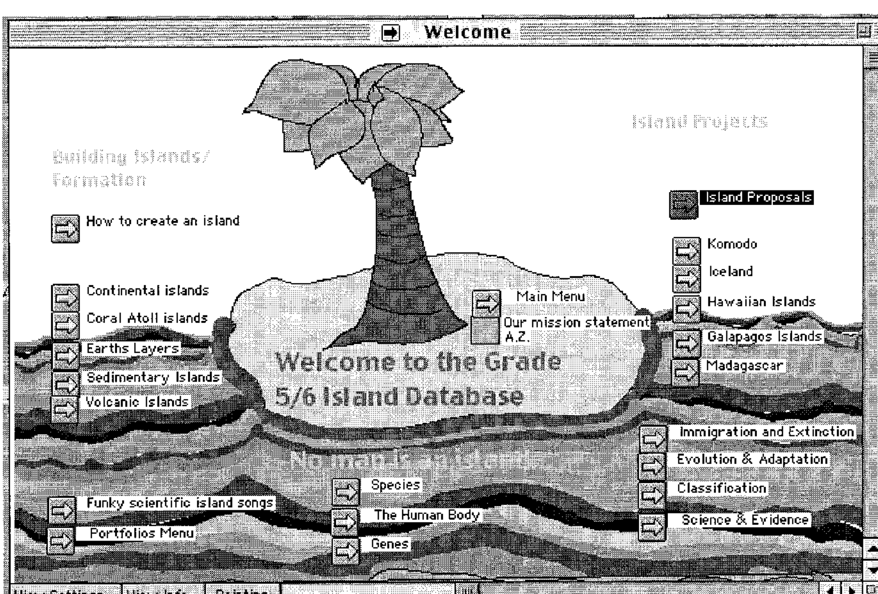

FIG. 3. Island database Welcome View—a look at areas of study that emerged throughout the school year stemming from the island theme.

for his controversial theory of evolution (Quammen, 1998) The class began with a study of how islands were formed, then became curious as to how plant and animal species might have arrived at islands. It seems that if students are allowed an opportunity for the natural progression of ideas, they too can travel along the intellectual pathways of these great thinkers.

Effects on Student Learning and Discourse: students' use of Knowledge Forum for knowledge transforming discourse

In the context of this shifting pedagogy and learning environment, what are the effects on how students approach science and what they learn? Toward understanding the development of a new relationship between students and scientific knowledge, we follow the course of a discussion taking place over a 3-week period in the investigation of 'Islands and Island Biogeography.' Over the course of the investigation, the students (along with their teachers and student teacher) struggled to understand the principles of evolution.

The discussion occurred as children worked, both on the computer and off, to understand the evolution of the Komodo dragon. The discussion grew out of an offline context in which the group of students that were studying the Komodo Island invited students from the other island groups to watch a segment of a video about the Komodo dragon. Maddy, who was not in the Komodo group, reflected upon what she had seen in the video and, working in the Knowledge Forum database, created a note in the Komodo view. In her note, Maddy proposed that Komodo dragons were related to the dinosaurs and 'maybe somehow a dinosaur slightly evolved.' The teacher built on to Maddy's note, asking her to clarify her ideas. Maddy responded with the following Knowledge Forum entry:

> *Maddy*: *How did the Komodo dragon evolve*? Well, if you look at the lizardy tongue of the Komodo dragon, and their skin type, it resembles a lot of dinosaurs, so I was thinking that maybe they were related and the Komodo evolved from a type of dinosaur. What does everyone else think?

Two things are striking about Maddy's note. One is that she is from another island inquiry group and yet became interested enough in the Komodo topic to become involved in this inquiry. The second is that she asks, '*what does everyone else think?*' She solicits help from her classmates in trying to understand the relationship between Komodo dragons and dinosaurs. The notion that ideas get voiced and then shaped by the perspective of others is emerging in the database.

Maddy's note ignited a sustained discussion that, by its end, involved the entire class. The initial responses to her question were from members of the Komodo group. It became evident from these responses that there was debate and lack of clarity within the Komodo group itself. In turn, this lack of clarity among members of the Komodo group sparked numerous discussions and instigated an intense search for resources to support claims, heated debates over whose graphic representation was most accurate, and a collective, class-wide effort toward understanding the evolution of the Komodo dragon.

What follows is an overview of the discussion. Some important points to consider while examining the following set of student interactions are:

- the interweaving of online and offline discourse;
- student reflection on the processes of science;
- student reflection on themselves as learners;
- collective contribution to knowledge building;
- how the availability of the student interactions in Knowledge Forum alerted the teacher to issues that needed clarification and to concepts students were heading toward, both of which helped to move the curriculum forward in a progressive manner.

Reid, one of the students from the Komodo Island group, took on Maddy's issue. He worked independently to conduct library research. He also talked with a visitor to the classroom who had been to Komodo and had told him that the Komodo dragon looked a little like an alligator. Reid then entered his work in the Knowledge Forum database by creating a graphic (Fig. 4) and accompanying explanation.

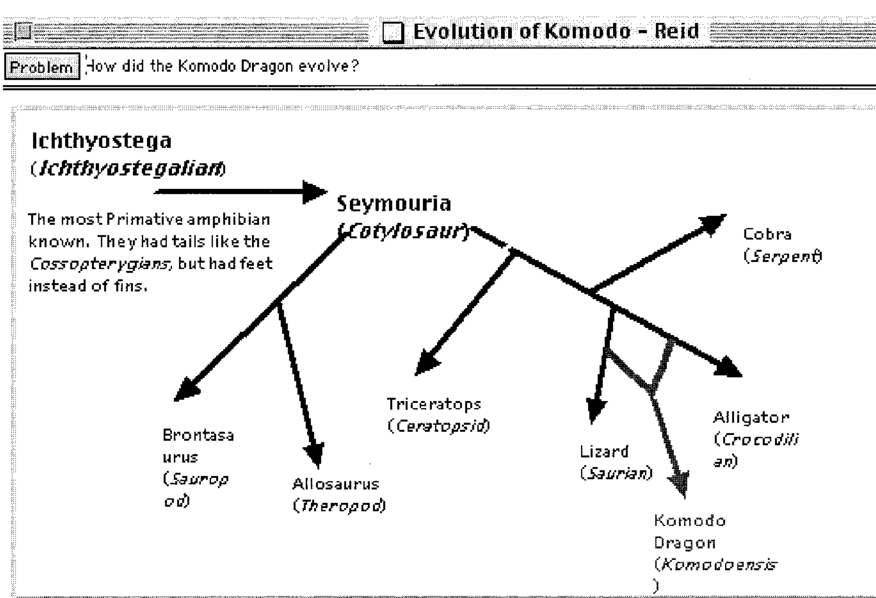

FIG. 4. Reid's figure.

Reid: Maybe they evolved from the alligator dinosaur and died out everywhere but Komodo because it had a good habitat.

Another Komodo Island student, Daniel, responded to Reid's note with an alternative graphical representation (Fig. 5).

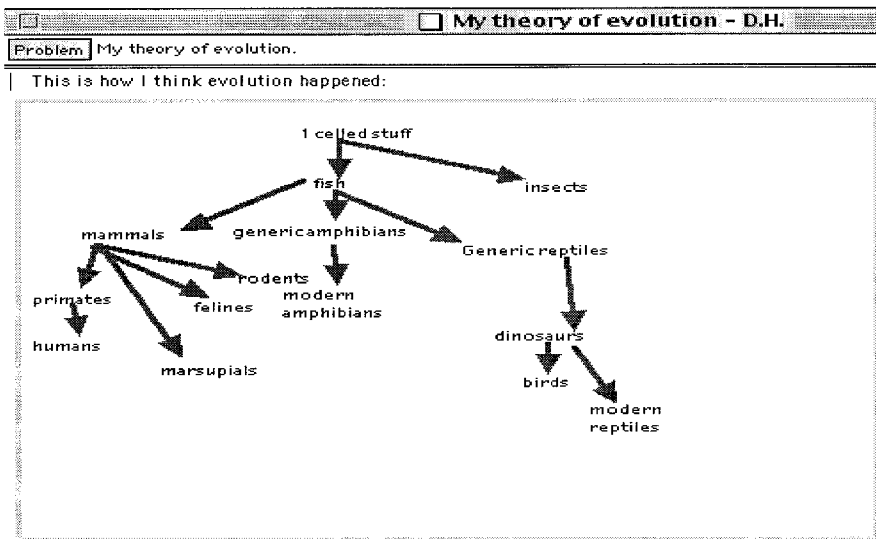

FIG. 5. Daniel's figure.

Daniel: I really don't understand R's theory. It is complicated and he hasn't told us exactly what his resources are.

The next day, during Inquiry Time, a computer projector was used so that Reid and Daniel could stand in front of the class to present their ideas about the evolution of the Komodo dragon. Students began to debate the two views put forward by Reid and Daniel. During the course of their heated discussion, the class became divided, based on their personal beliefs or opinions, between the two positions. A small handful of students slightly agreed with Reid's graphic, but were unable to explain it because they were unfamiliar with terms such as 'Seymouria.' Another group of students argued that amphibians could not evolve into reptiles. Reid retorted with, 'Basic evolution! The amphibians started to walk on land.' Some students had interpreted his graphic to mean that Komodo dragons were the result of alligators and lizards mating. Many students favored Daniel's note to Reid's. At this point, researchers Reeve and Lamon suggested a lesson on reproduction, and students began to wonder: what makes a species?

After the face-to-face meeting, the debate continued online in the Knowledge Forum database:

Daniel: If not lizards, what were they? I think that they were a type of reptile.

Amy responded with a note which is reproduced in Fig. 6.

Komodo - A.Z.

My theory is that Komodo dragons evolved from lizards or dinosaurs.I am not sure they evolved from alligators. I think to answer this problem we have to go very deep and find stuff like the blood or skin type of the Komodo or Alligator and compare. I will do this!!

I was also wondering why Komodo dragons have not adapted to there cilmate very well? The reason I say this is Komodo dragons get to much sun and have to go inthe shade to cool off. This sounds kind of silly butif the adapted to there climate they would not have to do this.

This theory came from a paper I was reading a couple of days ago. The paper was about turtles and how they live in many places but have not adapted. Are there certain creatures they do not need to adapt? Are komodos one of those creatures?I am very interested in finding out about whee Komodos evolved from maybe they have some relation to turtles.

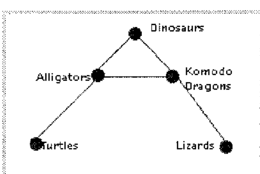

FIG. 6. Amy's theory.

In addition to comparisons with other species, students now turned to word meanings in search of the truth. For example, Matthew looked up the meaning of the word 'dinosaur' and found that it meant 'terrible lizard' (see Fig. 7).

Dino-Sauraus - Matthew

New information The word dino is latin for terrible and the word saurus is Greek for lizard. So the word dinosaur means terrible lizard. That is why I support D.H.'s theory over Reid's it is less complicated and more accurate Reid's theory doesn't make sense to me. What I understand from Daniel is that the reptiles are a family and inside that family lizards evolved into komodo dragons and geckos and etc. Down below each graph is shown and look how less simple more accurate and easier to understand. We do not need a deep understanding on something simple. 1 The yellow number 1 is a link to D.H's graph. 2 if you see both you will understand.

1 D.H.. (Jan. 22, 2000). "My theory of evolution" [Knowledge Forum™ Note]. ICS - Islan [Online]. Available: database address [date referenced].
2 Reid. (Jan. 14, 2000). "Evolution: Komodo Dragon" [Knowledge Forum™ Note]. ICS - Island [Online]. Available: database address [date referenced].

FIG. 7. Matthew's note.

Matthew's note resulted in the following exchange in the Knowledge Forum database:

Julian: They named dinosaurs terrible lizards because when they saw the bones they thought they were terrible because of how big they were.

Reid: Dinosaur comes from the Latin and Greek words meaning terrible lizard. DINOSAURS WERE NOT LIZARDS.
Maddy: The name dinosaurus could have been wrong. People could have just thought that a dinosaur looked like a lizard so they jumped to that conclusion. Also if the name was improper scientists have other names for dinosaurs (scientific names). Do you think that maybe the people that came up with the name (terrible lizard) were incorrect? Cause well maybe they just thought dinosaurs looked like lizards and that's the conclusion that they jumped to. 'What is in a name?' E.g. People call Whales fish when REALLY they are mammals.

Student inquiry around the evolution of the Komodo dragon actually moved the curriculum forward. In a knowledge-building classroom, ideally, the teacher carefully times and shapes interventions to respond to student interest while incorporating issues that the teacher knows are important to the subject matter and inquiry process. This is obviously easier to do with the support of a team, such as was the case here. The teacher and student teacher were able to prepare an introductory lesson on taxonomy, using cats and humans as examples in the animal kingdom to classify.

Natalie followed up by researching the taxonomy of the Komodo dragon and came up with her own way of explaining what a taxonomy is to the class (Fig. 8).

Matthew: Natalie, you don't even know what we're arguing about and it has nothing to do with the class of the animal.

Timing plays an important role in a knowledge-building classroom, and opportunities of need and interest are seized to keep the flow of knowledge creation as the top priority. At this point, the researcher (Lamon) found an

The taxonomy of the Komodo Dragon – Natalie

Problem What's the taxonomy of the Komodo Dragon?

New information :
When I was looking through a book on the Komodo Dragon I came across with the taxonomy of the Komodo Dragon as shown below. I've put in brackets below the English interpretation of the Latin names I know so far:

Kingdom: Animal
Phylum: Vertebrates
Class: Reptilia (Reptile)
Subclass: Diapsida (?)
Superorder: Lepidosauria (Pleasant-lizards)
Order: Squamata (Scaly)
Suborder: Sauria (Lizards)
Infraorder: Anguimorpha (snake-like)
Superfamily: Platynota(?)
Family: Varanidae(?)
Genus: Varan*us (?)*
Species: V. k*omodoensis (Komodo Dragon)*

But what does the Taxonomy mean?
I found out that the Taxonomy is how animals get organized into groups. For example...the Species would be me, Natalie, the Genus would be Grade 5/6 in Bev's class. The Family is ICS. The Order is Toronto, the Class would be Canada, the Phylum is North America, the Kingdom is Earth.

The Komodos first direct ancestor appeared approximately 70,000,000 to 100,000,000 years ago.

FIG. 8. Natalie's explanation of taxonomy.

important resource on the Internet and added it to the database in the Komodo View. The article talks about the Komodo dragon being a member of the class *Reptilia* and related to, not descended from, dinosaurs.

Liz read Lamon's resource, highlighted a crucial part and built on to the taxonomy discussion with the new information. For this particular student, it was a turning point in her ability to create an informative build-on. Up until this point, she had hardly ever built on to a classmate's ideas, except to give critical advice, such as pointing out spelling errors.

Throughout the 3-week exchange, Reid had been trying to refine his understanding and, subsequently, his explanation of the Komodo dragon's evolution. The majority of the class still did not understand his point. Reid took this misunderstanding as a challenge to revise his work rather than a reason to give up. He came up with what he thought was a clearer and more understandable representation (Fig. 9).

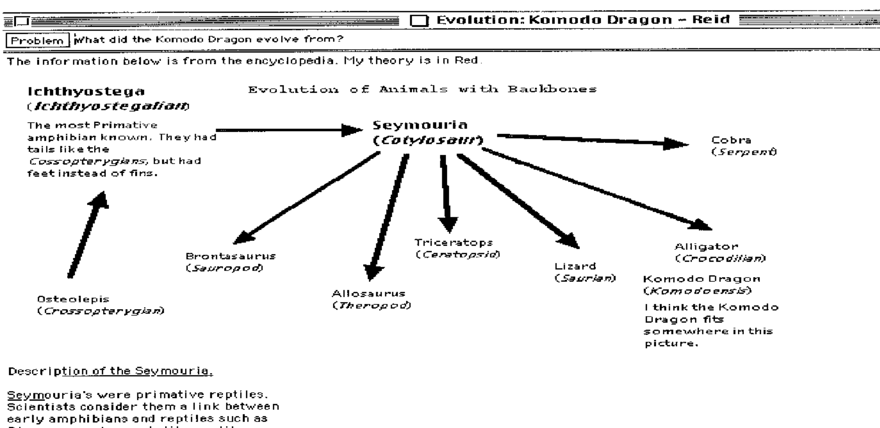

FIG. 9. Reid's representation.

When Reid finally redrew his chart and stood up in front of the class and said, 'Here is what I was trying to say and here I've tried to redo it so it's clear—what does everyone think?' the class made a collective, 'Yes, we've got it!' Reid threw his arms up in the air and shouted, 'Yes!'

Other students added build-ons to Reid's note in the database with comments such as:

> *Matthew*: Reid thank you for making this graph more clear. I understand now.

After Reid's note had been read and understood by all, Amy decided to create a consensus note in which she archived the progression of ideas relating to the evolution of the Komodo dragon, and included students' graphics shown earlier as well as her own (Fig. 10). It becomes a record of the classroom community's knowledge creation journey and the struggle to understand the evolution of the Komodo dragon. This type of note,

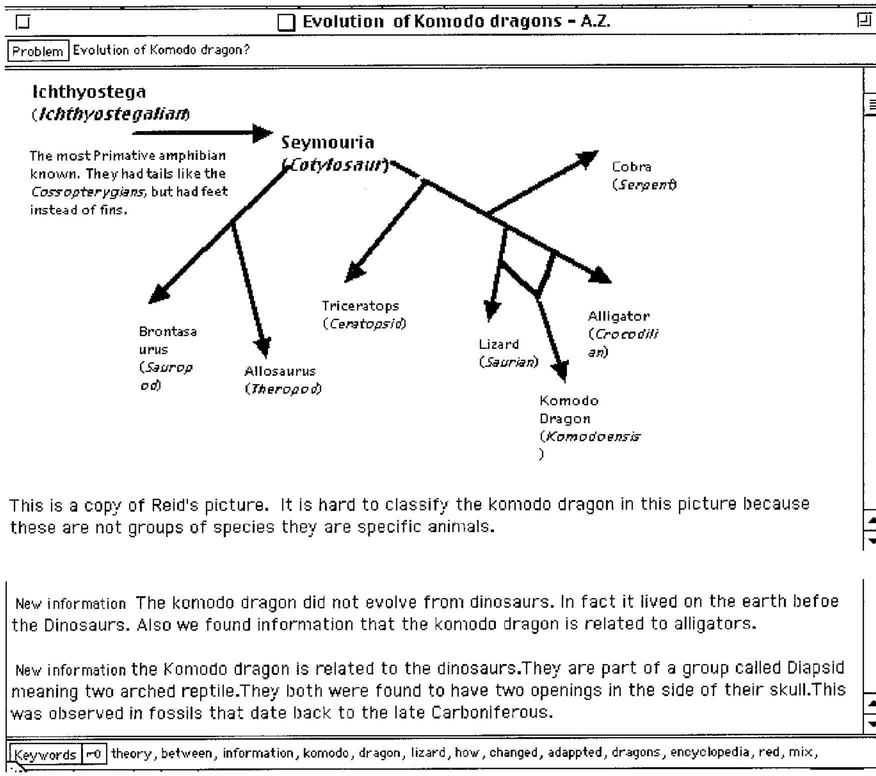

FIG. 10. Extract from Amy's teaching note.

coined the 'teaching note' by Reeve (1998), strengthens and highlights overall rather than individual progress.

Students' work on the evolution of the Komodo dragon led to further understanding of evolution in general. At the end of the unit, students took charge of creating a new view in the database entitled *Evolution and Adaptation*, which provided examples of students' progression from a pre-Lamarkian to Darwinian theory of evolution.

Dimensions of Understanding

The Komodo dragon discussion also gave birth to a side debate concerning whether the age of a resource determined its validity:

> *'Well, one resource says that the Komodo dragon evolved from the dinosaur and the other resource says that the Komodo dragon did not evolve from the dinosaur. It's so hard to figure out which one is right because now resources go in completely different directions. Anyway, how can they be sure, because no one has ever seen a dinosaur.'*

> *'Just because something was put out by scientists, is it right? The theory Reid is using is about 30 years old.'*
> *'WHAT is wrong with a little evidence? Scientists may be wrong sometimes but they also can be right. Yes, scientists thought the Earth was flat at one point but they corrected their mistake in time. Scientists have theories that took them YEARS and YEARS to come up with and get AMAZING evidence, whereas our theories just take seconds with little evidence.'*
> *'As evidence progresses through time, so does science. Science theories cannot just come out of nowhere. They have to be supported by evidence. For theories to change, there has to be new and better evidence. Yes, science may be wrong, but to disagree with it, you have to find some better evidence.'*

This debate was one of the most exciting, yet worrying, for the teacher. Caswell did not want her students to start to disdain books (especially those written over 30 years ago!) and worried that they would prefer Internet resources to going to the library. It was shaky ground for the teacher, who felt as though she was in a philosophy of science course that Thomas Kuhn would be better prepared to manage. After all, he wrote the book on paradigm shifts in science and how scientific thought has progressed throughout history. That is not usually an area covered in teacher preparation courses. At the same time, she could see that students remained eagerly in pursuit of their Komodo questions, not getting bogged down with ideas about the nature of science.

It was also exciting for the teacher to see that the knowledge-building activities of the students were not confined solely to activities inside the classroom. A second area of work borne out of the Komodo dragon discussion occurred when a new bill, the Species at Risk Act, was introduced in Canada's Parliament. A group of the Grade 5/6 students (who earlier in the year had created and worked in the Species View) was opposed to it. They began to gather resources and to revisit the database in order to use information they had learned about species to put together a letter to the Environment Minister, pointing out reasons to reconsider the proposed Species at Risk Act. In our thinking, these Grade 5/6 students represent the kind of people Gardner craves: 'human beings who understand the world, who gain sustenance from such understanding and who want—ardently, perennially—to alter it for the better' (1999).

What the teacher witnesses in these settings is the multilayered learning that students are experiencing. On one level, you can see the content area being covered and students learning quite rapidly. On another level, you know that they are becoming prepared for a thinking life, the philosophical level which children are so natural at. At a third level, they are developing metacognitive skills which enable them to articulate thought processes and to highlight their needs as learners. And of course, there is the technical level of learning; everything about the use of the computer: graphics, keyboarding skills, etc.

Classroom Learning Can't Live By Technology Alone

One of the successes of Knowledge Forum is its ability to keep students' questions, ideas and knowledge *alive* because notes in the database are always available for search, retrieval, comment and revision. Also, it provides an even playing field for students. That is, because discourse takes place online and students' focus is on problems of understanding and advancing knowledge, gender issues do not seem to arise. Boys and girls work comfortably together on problems of shared interest.

The Knowledge Forum environment provides a structure that gives life to the domain of science. The built-in scaffolds allow students to incorporate the language of cognitive processes (i.e. My Theory Is; I Need To Understand, etc.) into their everyday work. Knowledge Forum allows students' thoughts and ideas to be heard, archived, reorganized and reflected upon. For example, a group of students looked over some of the notes in the Komodo View and created a new View called 'Science and Evidence.' The note in Fig. 11 is from that view and shows the annotation feature of the software. The student was able to drag two similar notes into his own note for comment.

Students also create electronic portfolios in which they place notes they are proud of, notes that reflect their understanding and notes that show instances of knowledge-building discourse. For parent—teacher interviews, this is an accessible way of showing student work. The keyword feature allows students to build up a bank of scientific vocabulary. The Analytic Tool Kit (ATK) provides online assessment (Burtis, 2000) and reports on different sets of measures, such as the number of times a note is revised, how many build-ons a student makes and how many notes are read by whom.

The database may be able to provide the ideal condition to place ourselves, as Gardner urges, 'inside the heads of our students and try to understand as far as possible the sources and strengths of their conceptions' (in Bruner, 1996, p. 49). For teachers, this means the ability to take a close look at the ideas that students can manage within a domain. Lessons can

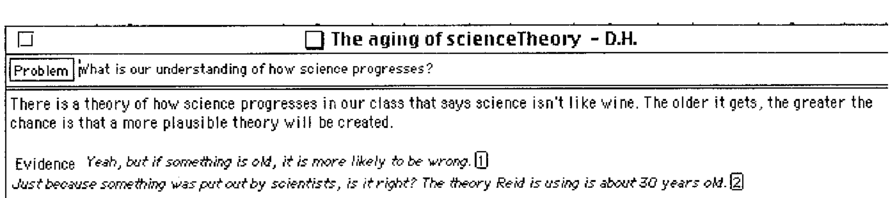

FIG. 11. Science and evidence note.

be designed to meet the needs of students as they struggle with principles in an area of study. For example, when students began to discuss the extinction of endemic species, two benchmark lessons were designed: one on immigration and extinction and one on Mendel. This led to further interest in the genetic diversity of animals and people. The curriculum and students' collective understanding continued to move forward.

Students occasionally return to a previous year's database in order to use or revise information. This is quite a contrast to typical school science binders—which contain the record of an individual's work (usually with pages missing or slightly ragged) compared to a database which is an accumulation of the work of the entire class for the year.

Although the technology provides these opportunities, knowledge building does not just happen with the installation of a bank of computers in the classroom; and the software cannot create instant episodes of knowledge building. The responsibility of providing stimulating lessons, modeling an inquiring mind and maintaining and building momentum in the classroom rests with the teacher (Lamon *et al*., 1999). It is helpful for the teacher to have an understanding of the deep principles of the domain, otherwise she/he may miss the cues from the children.

In our classroom, we were fortunate to have a researcher and teacher-researcher as well as a student teacher at hand to help develop lessons about Darwin and Wallace, the formation of islands, equilibrium theory, immigration/extinction theory, taxonomy of species, etc., on a just-in-time basis. The teacher read David Quammen's book, *The Song of the Dodo: island biogeography in an age of extinction*, as a resource to gain necessary scientific background information. Online discussions about unit planning and pedagogy as well as scientific content took place amongst teacher and researchers from August to November through the use of the Knowledge Society Network (an Internet Knowledge Forum environment). These discussions were based on Howard Gardner's book, *The Disciplined Mind*, and focused on the deep principles of evolution (and the lessons and activities that could be created to support these ideas), curriculum guidelines and coverage issues, as well as library and Internet resources and computer simulations.

Conclusion

The extended discussion about the evolution of the Komodo dragon shows how the students in Caswell's class could come to the types of views about science and learning that they expressed in the opening quotations of this article. We see knowledge-transforming discourse evolving out of students (1) engaging in scientific theory-making and debate, (2) coming to see themselves as contributors to knowledge, and (3) developing a collective approach to knowledge building.

Scientific Theory-making and Debate

Over the course of the Komodo dragon discussion, students experienced first hand that scientific knowledge is not a fixed entity—their current state of knowledge is debated, theories are put forward, arguments are made and countered, etc. Through the discourse, their knowledge is critically examined and refined. These students are problematising not only science concepts, but the enterprise of science itself—they are focusing deeply on science-making. Set against the backdrop of Wallace and Darwin, students come to understand more deeply the development of theories and other processes within the discipline of science: the importance of field notes, jotting down ideas and observations, taking time to synthesize, gathering data, comparing results, and talking with others. Learning science is no longer about learning the scientific facts that one is given, but rather, a new view of knowledge work begins to take root: science learning is about trying to resolve complex issues.

Contributors to Knowledge

Students also come to see that their ideas are worth something, that they have views to contribute to the evolving overall understanding. For example, when Reid feels challenged by the class to come up with a better representation, he demonstrates what Scardamalia calls 'Epistemic Agency': 'Knowledge builders take charge of their own learning, and are engaged at the highest levels in achieving community goals' (Scardamalia, 2000; in press). Reid's goal was the production of a piece of knowledge that was acceptable to the community and was consistent with the community goal of understanding the evolution of the Komodo dragon.

Collective Approach to Knowledge Building

Students also experience a sense of the power in working collectively to advance 'our' understanding. No one student (or the teacher or other individual) is responsible for the understanding that developed about the evolution of the Komodo dragon. Different students contributed to the progress that was made. For example, Maddy's initial question revealed a gap in understanding of which the Komodo Island group was not even aware. She comments on the collective aspect of learning in her portfolio note from Knowledge Forum:

> *Knowledge building is coming up with an idea and building on to that idea. Building on to an idea or a fact or even a theory or hypothesis. It's sharing an idea and adding on so it becomes a whole web of knowledge. I think that knowledge building is a great way to learn and share ideas. It is not only in the database that you build knowledge but you build knowledge in crosstalk or when you are talking with friends.*

> *I am the kind of learner who likes to not only figure something out using a resource but learn for myself. Experiment and take things to a new level, go as deep as I can in a subject that interests me. I also LOVE to debate and see if I learn anything new from that, or even help someone else understand.'*

Underlying the importance of ideas as 'improvable' is the culture of the classroom that respects at all times the right of a person to state an idea and the rights of others to test out and analyze the idea. This is a highly important point, because we all have to live with each other when 'Inquiry Time' is over. We still have to play on the playground each day with classmates whose ideas are different from our own. Respect for each other is stressed as the most important goal in knowledge building, and children generally get the picture quickly. It has been a deep pleasure to watch students take part in a heated debate, then, when recess rolls around, to drop the topic completely for a good game of soccer.

What is noticeable for visitors to Caswell's classroom is the students' ability to articulate the ideas they are working with and what they find surprising or puzzling. Children seem to enjoy the intellectual challenge of discussing abstract ideas, especially ideas and questions that they have formulated out of their own interests and curiosity in an area of study. The quality of questions and depth of discussion is remarkable. Knowledge Forum supports this because it gives students time to think, time to be heard and time to work with each other. This can be exciting for teachers and can support a change in pedagogy. It's like an 'Ah-ha! I didn't know children were capable of thinking like that!' And at first you think it is just a fluke, everyone is having a good day. Then it happens again and again, the culture of inquiry is happening and you, lucky teacher, are in the midst of a creative and challenging place.

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NOTE

1. This technique was developed by Joan Moss and Elizabeth Morley and has been used successfully in the lab school at the Institute of Child Study to introduce children to difficult texts such as Shakespeare's plays.

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