3 "You Ought to Get a Book and Do Some Research, Too": Learning through Language in Math and Science

> If you had a million dollars to spend, a million dollars more or less, to spend on anything you wanted to spend it on, and you decided to spend it on ten different things . . . , what ten things would you buy, could you buy, for a million dollars, no less, no more?

It is a Monday in October, and Carin Hauser poses this question to her twenty third-grade students at Louise Archer School in Vienna, Virginia. Then to each of them she hands a "check" for $1 million and says that now they belong to the Million Dollar Club. With the check comes a one-week assignment: to keep a notebook of their wishes and an accurate list of prices for those wishes—ten items, no less—plus some "proof" of the prices: newspaper clippings, manufacturers' lists, catalog entries, etc. Following the assignment comes a small barrage of questions: "Could we get more than ten things?" ("Sure, if they don't total more than a million dollars.") "Do they all have to be different?" ("At least ten of them do—so you'll have to find different prices in different places.") "Do we have to include the tax?" ("If you want to, but I won't require it.")

Then comes the most challenging part. "What," she asks the children, who are seated around their "tables" of four desks each, "are some things we could buy with our millon dollars?" "Ice cream!" says one, and they all laugh. "I'd buy a 727," says another. "Could you buy that for a million dollars?" asks Hauser. "Try to think how you could find out the price of a 727." Other suggestions come forth, revealing different abilities to estimate values: "an expensive concert," "a Cabbage Patch doll," "a trip around the world." "I'd have a party for everyone!" says another, and they all cheer. Then Hauser urges them to think about "important" things they could use the money for, and several suggestions come forth: "try to stop air and water pollution," "build a hospital," "give to charity."

Having used the discussion to touch on other values besides quantitative ones, Hauser now brings the talk back to mathematics, with her emphasis still on creative problem solving. "Now," she says, "where can we look for the prices of the things we'll buy?" There are some seconds of silence as the children ponder. Hauser waits for their responses. Finally, one child says, "You could look in the newspaper, at the ads." Another says, "And you could also look at the other ads, the classified ads." "That's right," says Hauser. "Where else?" "How about catalogs?" suggests a third child. "We sometimes use the Sears catalog." Hauser duly notes all the suggestions on the blackboard, thereby honoring the children's contributions and encouraging the children to use the suggestions as guides for their search.

When they seem to have run out of ideas, Hauser produces one of her own. Holding up an issue of the *Washington Post,* she turns to the business section and within that to the listings for the New York Stock Exchange. "I was thinking," she says, "that one thing you might want to buy would be stock in a corporation, and this is the part of the newspaper where the latest prices of stocks are listed every day." From here, she explains a bit about prices per share, enough to show the children how they could begin to understand the listings.

In the last phase of the teacher-led dialogue, Hauser asks the students to suggest the math skills that they would need to do the ten-item, million-dollar assignment. "Addition," "subtraction," "multiplication," "division" come in rapid succession. To these Hauser adds, "How about estimating?" in reference to exercises the class has been doing recently. "Oh yeah!" says one child, and several others nod vigorously, as they begin to see how they might apply their study.

In Carin Hauser's class, both math and science are learned in this highly interactive, language-rich fashion. As this lesson illustrates, the conventional mathematics of individual computation will eventually arise out of this assignment, but in a more realistic, *inductive* way than that provided by the usual assignment in the math workbook. What might in most classrooms be an abstract exercise becomes in this situation a tantalizing class project, with each child anticipating his or her own discoveries, as well as those of the others. Indeed, what makes this project particularly exciting is that it does not seem like a "math problem" at all, but an opportunity to solve a puzzle of one's own devising. The mathematics arises inductively out of the child's incentive to make the prices match the magical figure of one million. For the children who are already able to manipulate such operations as multiplication and division, the assignment would still offer a challenge. For those who are just learning their multiplication tables, the million-dollar problem would let them apply what they know and give them incentive to learn more. For all the children, this problem provides an effective way of teaching them *how big* such numbers as 1,000,000 really are—an awareness all of us could use as we try to understand such concepts as budgets and populations.

By creating a realistic problem of this sort, Hauser is actually teaching an interdisciplinary lesson in reading (e.g., the different sections of the newspaper) and social studies (e.g., the consideration of social projects on which to spend the money). When mathematics, like other subject matters, moves away from prepackaged drills and toward solving realistic or imaginative problems, it inevitably becomes multidisciplinary, since every real issue cuts across all disciplines. One attendant virtue of this is that it enables teachers to meet curricular objectives in several areas through single projects.

In such an environment, mathematics becomes intimately involved with language. Hauser's using the students as her principal resource for ideas and examples necessitates her giving the students frequent practice in questioning, interpreting questions, and speaking within a large group on a problem-solving task. Solving the various parts of the problem will also require their reading and interpreting some unfamiliar, "adult" texts, including newspapers, magazines, and catalogs. This particular problem will not require much writing by the students, though they will no doubt be writing and revising lists of possible items, plus organizing all their data—items, prices, "proofs"—in an understandable format.

On the same morning that she presents the Million Dollar Club, Hauser also engages the students, divided into two groups of somewhat differing preparation, in other math activities that require group interaction and a more substantial amount of composing. She leads one group of fifteen, the "blue liners," in a conceptual exercise on multiplication. Standing before the students, who are gathered on the carpet in one corner of the room, she drops a handful of blocks into a metal can. She asks the children to listen and to venture guesses at the number of blocks she is dropping. The children raise their hands to guess. She repeats the action several times, each time using the same number of blocks. Then she asks the multiplication question: how many sounds have they heard altogether?

Again, her method is inductive, challenging the students to think from the particular instance to the abstract idea. These children are just beginning to learn multiplication tables, and this lesson is meant to show them the vital connection between the real problem and the mathematical symbolic operations we can use to solve it. By using the entire group to solve the demonstrated problem, she is also giving the children a social incentive to solve it; the game gives them the incentive to learn the arithmetic tools.

The next step in the lesson logically follows. Hauser asks the children to suggest problems of their own—situations that can be resolved through the same tools. The children think for a few moments; then several raise their hands. As a child states a problem, everyone in the group tries to solve it. When someone arrives at the correct answer, Hauser proceeds to the next analytical step: she asks the child how he or she arrived at the answer. Again, the children become more aware of the mental process of translating actual situations into problems that mathematics can solve. By making it necessary that the children listen to understand the problem and then express their processes in words for each other, she makes the learning process conscious. This method also makes it possible for her to learn immediately how a child may be having difficulty with a concept. (A variation on this model is to have the children keep logs of how they solve problems or understand scientific formulas. This technique allows the child and the teacher to see where the child is having a tough time understanding.)

The lesson with the blue liners ends with Hauser's assignment that each child compose ten multiplication problems of his or her own, including "three good word problems that require multiplication." Later, I ask three of the children if they like to write their own problems. They concur, adding that they like their own problems better than those from a book "because when you write your own problems, you learn how to write them and you learn why things go where they do."

As the blue liners work on their assignments, the other five children, the orange liners, work both independently and in pairs on a different task. This is a more advanced group, with the children able to do simple multiplication and division with some ease. By keeping the tasks of the two groups different and by not being bound to a sequence of assignments in a workbook, Hauser has minimized the children's feeling that one group is "behind" the other. There is no evidence of the common distinction between the advanced learner, who is given more creative work, and the "slower" learner, who does programmed drills (or vice versa). While the fifteen create their word problems for each other, the five first solve a multistep problem that requires adding, subtracting, multiplying, and dividing; then each child creates his or her own problem on the same model.

The final step for this group is to exchange and solve one another's problems. As with the blue liners' work, the value of this problem-creating assignment is as much communicative and social as it is mathematical. As every teacher knows, creating problems for others to solve makes one sensitive to the perceptions and abilities of others, just as it forces one to think more strenuously about the concepts one is trying to teach. For both groups, the creative composing task will push the children to imagine problems that they *cannot* yet solve, as well as those they can. For example, in creating their own multi-operational problems, the advanced group comes up with numbers that will not divide evenly and with negative answers that will then need to be multiplied. These results challenge the students to go beyond their current knowledge.

The last part of the morning in Carin Hauser's class is spent on science; specifically, on the students' developing research projects on dinosaurs. The class has been working about a week on the assignment, which will result in every child's preparing an illustrated booklet. Each child has chosen his or her "own" dinosaur (almost all the choices are different) and has been taking notes from the many books in the "dinosaur library," most of which have been loaned to the class by the children themselves.

This research period begins, as have others, with the whole class discussing "research questions" posed by its members. One questioner is David, who's having difficulty finding information on his choice, the Trachydon. Immediately, two others tell David of books where, in the search for their own dinosaurs, they've found the Trachydon. Other questions are similar and lead to similar kinds of help. Hauser then asks the children if they have been using the indexes and the tables of contents. Most nod their heads or murmur affirmatively. She tells them the researcher's trick of "reading around" in books, as well as reading the pages referred to by the index or contents pages. She tells them that frequently they'll find good information where they don't expect to. Two of the children relate instances when that occurred for them.

Before dismissing the group to continue on their individual searches, Hauser asks them to suggest why the group discussions of research are useful. Quickly, three ideas come forth: (1) the group gives help when "you ask for it," (2) "you might someday have a problem that someone else has today," and (3) "you might hear someone say something that will help you now." These responses are gratifying to Hauser because, as she tells me later, one of her hardest tasks with these third graders is to help them learn to listen. "It's a real sign of progress," she says, "when they want to add to, embellish, what someone else has said, or to answer thoughtfully another child's question." Consequently, she places great emphasis on working in groups, large and small, in her class.

Though the products of the dinosaur research will be unique to each child, the spirit of mutual help pervades every aspect of the project. During the half hour following the research discussion, each child follows a different pattern of movement: from the bookshelves to his or her desk—where the child seeks information from the chosen book and jots down data—then to the "library" again or to another child's desk—where one child asks the other if he or she has found the answer to a specific question. The curious kibbitz, wondering what startling facts others have come across today, while Hauser answers individuals' questions or asks a child how he or she is progressing.

The children do not conduct their study haphazardly, going from book to book and taking down information at random. Rather, they work from lists of questions that they have generated: "How tall was the Tyrannosaurus Rex? How many teeth did it have? Where on earth did it live?" For every question a child answers (all data are kept in a notebook), another, it seems, is added, usually to accommodate new data *already* discovered, or because another child, out of curiosity, asks it of the researcher. One of the many ways in which the children work together on the project is by reading their questions and answers to each other. In this way, children add to their lists the good questions that their friends have asked; meanwhile, they continually build one another's self-esteem, as each child becomes the "expert" on his or her part of the entire dinosaur project.

Each morning's research ends with the systematic sharing of facts by the four to five children at each grouping of desks. Hauser designates the first person to share; then each child takes a brief turn describing his or her discoveries for the day. She instructs the children to evaluate themselves on their hour's work, scoring their notebooks from 1 to 5, with 5 meaning "I learned something new and I did lots of looking." Each self-score is to be followed by the child's statement of why he or she deserved that score. Hauser wants the children once again to become conscious of their learning; moreover, the assessment provides the children with a day-by-day record of their progress. Most of the children give themselves 5s, and for most this is an accurate assessment. If nothing more, the score reflects their excitement and their sense of accomplishment. As David said to me earlier, as he carried a book from the library to his desk, "This is a great book on the Trachydon. You ought to get a book and do some research, too."

The dinosaur project demonstrates that under the heading of science, much learning goes on in Carin Hauser's class that could also and equally well be called history, communication, writing, and reading. As with the mathematics learning in this class, the inductive way of teaching, by which the children gain knowledge on their own incentive and with one another's aid, is always language rich and is therefore always interdisciplinary. Note also that the science learning consists not only of biological/archeological "facts," even though the children do find a remarkable amount of such data. The most important scientific principles that this research method teaches are principles of investigation: the children learn how to look and how to listen; they learn how to cooperate with other learners; and they learn that the patient, careful search for knowledge is almost always rewarded with discovery. These children may not yet be in the traditional science laboratory, but they are growing adept at the basic skills they will need there.

Carin Hauser Comments on Her Teaching: Hatching Experts

Jan wanted to find out about the duckbilled dinosaur. She started her research by listing these questions in her notebook:

1. How do scientists know duckbill has the bill?
2. How did duckbill get away from danger in the water?
3. What was the closest relative of the duckbill?
4. How many bones of duckbill have been found?
5. What is the duckbill's main diet?
6. Why does duckbill have two names?
7. Why does duckbill need a duck bill?
8. How big are duckbill's footprints?
9. Where are duckbill's fossils found?
10. How long are duckbill's teeth?

These questions directed Jan's research. Along with her third-grade classmates, who were investigating other dinosaurs, she read many books and magazines in order to resolve the questions that puzzled and intrigued her. She also added more questions to her list, questions that showed her growing expertise.

Through reading, writing, and sharing with each other, my students become true experts on their topics. They have no difficulty creating the main vehicle through which they share their knowledge with others, their published books. Through the research process, they become experts; thus, they can write with a great depth of information. Before Jan started her first draft of her dinosaur book, she wrote in her journal:

> I feel I know enough about duckbill to write two different reports. Doing research was long and tiring. Duckbill is very interesting. I learned a lot. If someone said, "Duckbill had only 25 teeth!" I would know that person didn't study duckbill, because he had 2,000 teeth!

Jan wrote her book about duckbill with imagination, humor, and the voice of an expert. She was able to do so because she immersed herself in her topic through her reading and talking with her fellow researchers. This is the beginning of Jan's book:

> If you went back into time onto a marshy shore in North America and you saw something like a duck swimming towards you, but when it stood up, thirty feet long, 16 feet high, it did not look like a duck except the bill, you actually would have seen duckbill, the duck billed dinosaur.

During the course of our dinosaur study, twenty other children, like Jan, became paleontological experts. Can the Smithsonian boast that many paleontologists who daily encourage and motivate each other in their research?

Our dinosaur studies took place in the fall. In January, we started a social studies unit on Native Americans. As a group, we read and talked about the history of the Native Americans in our country. From a broad base of common knowledge, the children set out to investigate research topics of their own, reading, viewing appropriate filmstrips, and visiting local museums in order to find out as much as possible about their Indian topics. They also used each other as resources. I am always tickled to see students list each other as "sources" in their research notes.

I found that my students' research skills became more and more sophisticated as the year progressed. Yes, they were using the card catalog, cross-references in indexes and encyclopedias, and the periodical guides, all skills that we traditionally teach through basal reading programs or library studies. But these third graders went far beyond the limited scope of such skills into the real "stuff" of research. They read and listened and wrote and talked in order to answer their own questions, not somebody else's, to find information, and to understand their topics. Their research was a form of problem solving, and like problems and puzzles, the research was not without its difficult points. For instance, a third grader often would ask, "How much of this big book should I read to find out about the Hopi Indians?" Too often, young children are intimidated by the bigger texts that might hold valuable information for them. I tried to help the children figure out which parts of the text they needed to read, and I also helped them make sense of complex information. Sometimes I even read parts of a text aloud to a small group or to an individual, and we discussed the information to make sense of it. The children made their own notes in their research notebooks; these notes reflected facts and data and, more important, the information they chose as significant to their search.

As the children grew more adept as researchers, they also became more decisive about choosing the form for sharing their information. With the end of the school year approaching, I still have a few students who write reports that are no more than an accumulation of facts, but this kind of writing is in the minority. Most of the children choose a form through which they can boast a real expertise on their topics.

The following excerpt is from the beginning of "Seven Sleeps with Running Elk," David's story about a Sioux boy. He had a particular interest in that tribe because his mother had grown up in Sioux City.

> First Sleep (Mon.)
>
> I rise with the sun. (That is a Sioux rule—to wake with the sun in the morning and go to bed with it at night.)
>
> I, Running Elk, am 8 winters and 7 moons old. Once again I have spent the night in dreams of the buffalo hunt. Will I never be 10 winters old?
>
> Like all Sioux boys, I have slept in a loose buckskin shirt that hangs below my knees. I wear this shirt day and night. I wear no underclothing.
>
> I also wear a small beaded pouch in the shape of a decorated snake. This pouch holds a piece of my umbilical cord from the time of my birth. It is strong magic to protect me and I will wear it all my life.
>
> I slip on my moccasins and go straight to my breakfast place in the tepee.
>
> Mother has prepared a bowl of soup and boiled buffalo. Other things I like are: wild rice, beans, turnips, cactus buttons, chokecherries, gooseberries, squaw corn, birds and your favorite and mine—buffalo meat! Sometimes, I have fish which I catch with a hook made from a mouse's ribs. And, if I do all my chores, I get a special treat called "Wasna." This is a cake of ground buffalo and wild berries.
>
> I think I hear Grandfather calling me to gather wood for the fire. It will be a long day, as Sioux children have many responsibilities. I also have to invite neighbors to the lodge, drive the horses to water, and spend extra time training my pony for that moment of truth—the buffalo hunt!

David's story reflected not only his expertise (he was very comfortable with his new knowledge), but also his excitement and pride in the whole process of his research. His book was full of treasures: real information, voice, honesty, and humor.

The children's research efforts took time. We spent about six weeks on the research and writing part of our Indian unit. As they read and talked about their topics, the children started to explore different ideas for sharing their knowledge. Class discussions on form allowed the students to see that they had choices, and their choices eventually evolved quite naturally.

In the Indian and dinosaur studies, the children had access to a variety of resources for their studies. In May, my class and I embarked on a different kind of project: we tried hatching chickens. I learned about chicken embryology alongside the students—I had vague recollections of a similar project during high school, but the details had long since escaped me. We had only a few books from the public library and my 4-H Leader's Guide for our book resources. Inside the incubator were our fourteen objects of study; we could weigh them and candle them (hold them up to light to see the shadow of the developing organs and blood vessels), but the children really couldn't "see" what was happening inside the eggs. My objective for the unit was for the children to learn about the development of the embryo, and I knew this would involve some unusual vocabulary for them. Because of our limited resources, I was curious to see how much depth there would be to the children's learning.

The children kept journals in which they recorded what we talked about each day as well as the observable development of the embryos. Most of the children's journals became a record not only of their study of the embryology of chickens, but also of their growth as active participants in class discussions. This was not a "hands-on" unit like our science units; what the children learned was mostly from class discussions. When questions were asked that no one could answer, we checked our books. At times, we could only speculate on the answers, using information we knew to be true in order to guess.

Here are some entries from Erin's journal:

> April 26 Are they gooey, squishy, and soft inside? Has the heart started to form yet? How come they're all dirty? Is the moisture inside? Do they have feelings yet? NO
>
> April 27 No. 8 egg—2 oz. No. 1 egg—1 7/8 oz. How come it weights less 3 days after?
> amniotic sac
> white—albumen
> little bubble—blastodisc
> When does the heart start to develop? 12 days? NO.
>
> May 1 Talked about journals. Ha-ha! We found out what the eggs weighed. We talked about journals. Still, how come egg No. 8 never changed its weight? Is the shell going to turn brown?
>
> We looked inside the egg. It looked like one of them had a heart. One of them was moving. One looked like it had an eye. How come Ms. Hauser cracked open an unfertilized egg? How did she know it was not fertilized?

> May 3 Today nothing really happens except got a little bigger. (Sorry I didn't have a lot to write about.) Today beak opens and closes. Goosebumps.
>
> May 15 Today me and Sandra found one egg cracked. You could see its beak and feathers. It was chirping. Some of the eggs rolled around. Someone told me that is a sign of life. I mean life outside of the shell. The feathers aren't downy yet. They—the feathers look dry and gooshy.
>
> PLEASE MAKE THE EGGS HATCH
>
> Later: When we came in from recess—the hole on No. 2 got as big as a walnut and 1/2. Before lunch it was about as big as a jelly bean.
>
> After: I saw the wing moving and its beak. Names for Egg No. 2: Early Bird, Willy, Miss H. No. 2
>
> "Egg 2 has hatched."

I was surprised to note that Erin tried to keep track of new, specialized vocabulary. This was vocabulary that we used during our discussions of the changes taking place inside the eggs, vocabulary that was unfamiliar to the children. Erin's journal became a place where she recorded much more than new words, though; she recorded answers to her own questions, as well as her feelings and reactions.

The children chose a variety of forms for sharing what they knew about embryology: illustrated books, articles for *Ranger Rick,* letters to uncles, question-and-answer brochures. One child wrote "The Journal of a Farm Girl." Erin chose to write from the viewpoint of a reporter, narrating the events of hatching day.

> EXTRA . . . EXTRA . . . 111's LATEST NEWS
>
> It all started when . . .
>
> "Erin, could you please move the chicken box off the back table?" said Miss H.
>
> I moved the box on a chair. When I put the box down I heard loud chirping coming from the incubator.
>
> "Miss Hauser," I cried, "I heard some chirping!"
>
> "Check again," said Miss H.
>
> Sandy walked to the table and peered through the incubator.
>
> "Erin," she whispered, "there's a hole in one of the eggs!"
>
> "Sandy, stop the kidding," I whispered.
>
> "Look for yourself," she said. I looked in. I saw a hole about as big as a jellybean. "Miss Hauser," Sandy and I called, "there's a hole in one of the eggs."
>
> Soon 25 people rushed toward us forming into a line. Miss H. peered in and said in a cheerful voice, "Erin and Sandy are right."

With these projects, as with the dinosaur and Indian units, the children not only expressed their expertise on the topics they studied, but they wrote with a voice that touches, and sometimes surprises, the reader. The voice—indeed, the entire writing—evolved naturally out of intense study done from a third grader's perspective, at a third grader's pace. All of the writing is memorable.

During the school year, we hatched more than chickens in Room 111. I witnessed the growth of experts. These experts learned to be aggressive questioners and researchers. They also learned to help each other in the process, from helping another student find a book to responding to a first draft. And so Room 111 hatched an entire cadre of embryologists, paleontologists, and anthropologists.