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ABSTRACT

Two pilot studies of a new science program called WEE Science were conducted in fifth-grade classrooms. The pilots lasted for 7 days in one of the classrooms and 9 days in the other. At the beginning of the program the students chose a science tradebook from among the many that the researchers, teachers, and librarians had selected and brought to the classroom. The students then formed groups based on the topics of the books and asked questions (Wondering) about the content. After choosing one of the "wonderments" to pursue further, the students formed and implemented a plan for investigating (Exploring). In each classroom, each student explored, working in cooperating groups of two or more. The students then explained (Explaining) to a group of their peers what they had wondered and what and how they had explored. The students' wonderments, activities, plans, and explanations were recorded in a science notebook that had been designed for that purpose. In addition, the classrooms were videotaped while WEE Science was in progress. The researchers analyzed the notebooks and videotapes to help them in their exploration and explanations of WEE Science. While the pilot studies were successful in that most students eagerly participated in all phases of the project, some problems were encountered which created another round of wondering for the researchers. Some of these were: evaluating students' work, responding to science misconceptions of students, teaching some students to record observations in their notebooks, deciding where WEE Science would fit best in the curriculum, and anticipating its reception in the science education community. (Contains 22 references. An appendix presents selected pages from the WEE Science Student Notebook used in the pilot study.) (Author/RS)

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WEE SCIENCE--INTEGRATING CONTENT AREA READING AND SCIENCE EDUCATION

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TECHNICAL REPORTS

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Abstract

Two pilot studies of a new science program called WEE Science were conducted in fifth-grade classrooms. The pilots lasted for 7 days in one of the classrooms and 9 days in the other. At the beginning of the program the students chose a science tradebook from among the many that the researchers, teachers, and librarians selected and brought to the classroom. The students then formed groups based on the topics of the books and asked questions (Wondering) about the content. After choosing one of the "wonderments" to pursue further, the students formed and implemented a plan for investigating (Exploring). In each classroom, each student explored, working in cooperating groups of two or more. The students then explained (Explaining) to a group of their peers what they had wondered and what and how they had explored. The students' wonderments, activities, plans, and explanations were recorded in a science notebook that had been designed for that purpose. In addition, the classrooms were videotaped while WEE Science was in progress. The researchers analyzed the notebooks and videotapes to help them in their exploration and explanations of WEE Science. While the pilot studies were successful in that most students eagerly participated in all phases of the project, some problems were encountered which created another round of wondering for the researchers. Some of these were: evaluating students' work, responding to science misconceptions of students, teaching some students to record observations in their notebooks, deciding where WEE Science would fit best in the curriculum, and anticipating its reception in the science education community.

WEE SCIENCE--INTEGRATING READING AND SCIENCE EDUCATION

Integrating Reading and Science Education--
On the Development and Piloting of WEE Science

PART I: THE PROLOGUE

Today's scientists, men and women alike, work in a highly populated universe, in pairs and teams. They are fully engaged with each other, strengthened by continuing interpersonal communications, and captivated by extensive legacies of print. Collectively and individually, they read and wonder without shame, explore in delight, debate and cajole daily, and explain in hearty celebration. The music and dance of the wonderment and the exploring and the explaining are testimony to a less brooding and less lonely human activity. Within this context, the seeds of WEE Science were nourished.

PART II: THE INTRODUCTION

Over an indeterminate period, we read and talked much about science, the teaching of science and the reading about science. We wondered together, aloud, as well as alone. We read together, shared wonderments, pretended explorations, and generated halting explanations. Finally, we installed our wonderments in explorations with students and teachers in typical classrooms.

What is WEE Science? It is a reading/science program designed to promote minds-on-science through reading and other activities for students in grades 3-5. The program is structured to result in improved science instruction following some of the recommendations put forth by Rutherford and Ahlgren (1990), as well as to make the instruction of science meaningful and non-threatening for the classroom teacher. As conceived, the program is not a cookbook set of instructions, implying a de-skilling of teachers. Rather, it is a program designed to promote the best thinking and language arts expressions that teachers and students have to offer.

Wondering, Exploring, and Explaining are the key strategies in WEE Science, and these same concepts provide the structure of our explanation in this linear medium. Consider first how we wondered.

PART III: WONDERING

> In the science classroom, wondering should be as highly valued as knowing (Rutherford & Ahlgren, 1990).

In this section we present some of the many wonderments that we generated about classrooms, teachers, science education, reading science books and writing science documents. In addition, we want to convince you about how much fun, in fact pure delight, wondering can be. We experienced it, as did fifth graders, and those to whom we have explained WEE Science sensed it. Meanwhile, we present some of our wonderments and give a trace of the thinking and justification which accompanied them.

- We wondered if students could read science in a way that closely resembles how scientists read. That is, could students become amazed, confused, interested, and angry? Could they exude confidence, pride, sadness and some of the other emotions and cognitions that readers of other genres experience?

Consider a scenario offered by one of the team members who previously worked in a laboratory that specialized in underwater acoustics research. He recalled the importance and excitement of reading the newest technical documents as they became available. The laboratory librarian would deliver the recent pieces on a large cart to each senior physicist, who would preview them and assign them to the junior team members. The team members would then read, wonder, re-read, challenge each other's ideas, collect data, make phone calls, get mad at each other, call in consultants, and often prepare their own written explanations of these wonderments.

These emotions and cognitions seemed to keep them on the cutting edge of their science--they were fueled by the driving forces of their own curiosity, and they crafted an understanding of those scientific documents.

- We wondered if the reading curriculum of typical elementary classrooms could share some of its time with science reading. Could such reading be authentic science reading and not a form of reading whereby students "practice content area reading by reading expository text?"

We became acutely aware of the fact that content-area reading, or reading to learn, is sorely absent from most elementary school classrooms. Estimates (cf. Goodlad, 1983; Mayer, 1987) suggest that fewer than 2 hours per day are devoted to reading and language arts in the classroom, and most of this time occurs during the scheduled reading and language arts time slot. A further analysis of these time allotments suggested that the total time given to reading activities of any kind--oral reading, reading to answer study guide questions, or independent silent reading--during content-area instruction periods likely accounts for only about 20 minutes per day. By far the bulk of this 20-minute block of time is spent in an activity referred to as "reading to answer study guide questions."

Supporters of content-area reading instruction suggest that, when it is taught and taught well, the skills and strategies learned will transfer to the successful reading in virtually all content areas. To support this claim, Spargo and Harris (1978), for instance, describe four levels of comprehension, based on Herber's (1978) list, that demonstrate a reader's competence in the content areas:

1. Vocabulary Comprehension (i.e., what do words and expressions mean?). Students develop a knowledge of the vocabulary of a content field and the ability to use word-analysis skills and context as means with which to deduce word meanings.

2. Literal Comprehension (i.e., what did the author say?). Students recognize, understand, and organize factual detail.

3. Interpretive Comprehension (i.e., what did the author mean?). Students begin to develop relationships among and between details and interpret their significance.

4. Applied Comprehension (i.e., how can this information be used?). Students develop metacognitive abilities and extend the meaning of the learned knowledge beyond its relevance to the assignment.

Our sense is that this list of strategies is reasonable, but woefully incomplete. It seems to represent faithfully which strategies would help to read basal science books and answer questions typically found on a science study guide, but the strategies only approach the kind of reading done by scientists. Where, in the above listing, are the emotions, the curiosity, the drive, and the search strategies needed to locate and understand relevant information?

- We wondered if elementary students could write like scientists.

Similar to content-area reading, research on task-driven writing, or writing to learn, revealed that such writing is all but absent from classroom science instruction, despite its recognized importance as a tool of learning, communicating, understanding, and being understood. Also, like content-area reading, task-driven writing has many distinct advantages that are purported to transfer across the curriculum. Tchudi and Huerta (1983), for instance, list the following persuasive advantages:

1. Writing about a subject helps students learn that subject better.
2. Writing about content has practical payoffs, both in school and in later professional arenas.
3. Content writing often motivates and inspires reluctant writers by giving them engaging subjects about which to write.
4. Content writing develops all language skills.
5. Writing teaches thinking skills.

In spite of these advantages, Applebee (1984) found, in his extended studies of task-driven writing at the high-school level, that the uses of writing were very limited. In the content-area arena, writing uses were generally restricted to "noncomposing" activities such as completing work sheets and practice exercises, writing paragraph-or-less responses to study questions, or taking notes. There is, he stated, "an imbalance in the kinds of instruction and practice that students were receiving. Although a high proportion of class time in all subject areas emphasized writing skills at the word and sentence levels, students were seldom asked to employ these skills at greater length--rarely even to construct a paragraph. . ." (p. 3).

We found rather persuasive the position that writing in science instruction can serve many functions. For example, essay writing can provide students with an opportunity to integrate new knowledge--declarative, procedural, and affective--with their preexisting knowledge (Edwards & Fisher, 1977). Keeping entries in learning logs can reveal problems, clarify thinking, and generate ideas and questions (Kennedy, 1985). Further, writing about a lifelike context may stimulate new interests and points of inquiry for the student (Kintsch, 1977).

Like reading, writing represents another activity in which "real" scientists engage, making it a valuable part of a situated learning program such as WEE Science. The following excerpt from Latour and Woolgar (1979) provides an excellent description of the role writing plays in a science laboratory, in this case the Salk Institute:

> [The scientists] are compulsive and almost manic writers. Every bench has a large leatherbound book in which members meticulously record what they have just done against a certain number. This appears strange because our observer has only witnessed such diffidence in memory in the work of a few particularly scrupulous novelists. . .[When] the observer moves from the bench space to the office space, he is greeted with yet more writing. Xeroxed copies of articles, with words underlined and exclamation marks in the margins, are everywhere. Drafts of articles in preparation intermingle with diagrams scribbled in scrap paper, letters from colleagues and reams of paper spewed out by the computer in the next room; pages cut from articles are glued to other pages. . .[For] the observer, then, the laboratory began to take on the appearance of a system of literary inscription. (pp. 48, 49, 50) Or, as Knorr-Cetina (1981) so succinctly states, "In the main, it is the scientific paper (or its equivalent) which confronts us as the removable and removed 'end-product' of research." (p. 94)

• We wondered if the classroom *context* could yield to the demands of scientific reading, writing and learning.

Excerpts from the same study (Latour and Woolgar, 1979) portray the scientists' workplace in an interesting way and help us explain our wonderment about science in the classroom.

> A scene which represents to the observer the prototype of scientific work in the laboratory: a desk belonging to one of the inhabitants of the office space is covered with paperwork. On the left is an opened issue of *Science*. To the right is a diagram which represents a tidied or summarized version of the data sheets lying further to the right. It is as if two types of literature are being juxtaposed: one type is printed and published outside the laboratory; the other type comprises documents produced within the laboratory (p. 48). Almost without exception, every discussion and brief exchange observed in the laboratory centered around one or more items in the published literature (p. 76).

Our wonderment is firmly based on the apparent disparities between the typical classroom and the laboratory space portrayed above. These dispartities include: (a) the free wheeling sorting of documents and near documents in the laboratory space and the need for orderliness and systematic completion of tasks in the classroom; (b) the free and more or less casual exchange of ideas in the laboratory space and the need for some teachers to be brokers of most classroom communication; and (c) the availability of equipment, supplies, "counter tops," and storage facilities in the laboratory space, and the dearth of such amenities in classrooms. These disparities appeared formidable to us.

• Could we create an environment in which students would work in project teams, somewhat similar to a laboratory environment?

Our wonderment about learning science in project teams was thought to be a form of cooperative learning. Research on cooperative learning as a classroom instructional technology and performance enhancement technique has been reported in the literature since the 1920s. Slavin (1980) defines classroom cooperative learning as "classroom techniques in which students work on learning activities in small groups and receive rewards or recognition based on their group's performance" (p. 315).

After we analyzed Slavin's descriptive system, it became apparent to us that the WEE Science technique we were conceiving was not a fully cooperative learning technique. Rather, it appeared to be more closely aligned with the cooperative technique described by Edwards (1993) as Co-op Co-op. Co-op Co-op students are encouraged to explore their own interests in the subjects. The role of the team members is to research different materials and locate them. The students select their own topics, and there is relatively little interteam competition.

WEE Science does, however, appear to benefit from much of what cooperative learning entails and helps to situate it as a group-related instructional technology. Several aspects of the cooperative structure of WEE Science show signs of having important positive influences on student learning. For instance, Slavin (1980) points out that for high-level cognitive learning outcomes, such as those which we hoped to attain in WEE Science, "structured cooperative techniques that involve high student autonomy and participation in decision-making may be more effective than traditional individualistic techniques" (p. 337).

Webb (1982), in her review of the research on student interaction and learning in small groups, discussed the positive relationship between giving/receiving help and explaining to peers--both constants in the proposed WEE Science--and achievement. She concluded that motivation and satisfaction increase in group structures, while anxiety decreases. She also suggested that heterogeneous grouping techniques like those planned in WEE Science may be very beneficial to the students as they learn from others, gain wider perspectives, and resolve potential conflicts.

- We wondered whether we could create an environment that looked like good science.

"Without initiation into the scientific spirit, one is not in possession of the best tools which humanity has so far devised for effectively directed reflection" (Dewey, 1916). Unfortunately, students in the United States consistently score near the bottom in any measure of scientific literacy. According to Applebee, Langer, and Mullis (1987), only 7% of the students can draw conclusions using detailed scientific knowledge. One answer to this unfortunate state of affairs might be improved science instruction. However, elementary teachers appear to have a negative attitude toward science and science teaching. If this is true, then it is unlikely that improved science instruction will come from them.

In addition to these reminders, another sobering thought presented a challenge. It is best conveyed in a sad story. Several years ago in our community, a group of inspired high school teachers organized to remake their school district's history curriculum. The curriculum development criteria they applied focused on skills they had determined were those used by historians. They described, analyzed, and illustrated these skills, and they taught them to the students, via a series of workbooks, student exercises, data collections, and simulations. In one of the final stages of the developmental process, a historian from the university community was invited to witness a class in action and render his evaluation. Much to the surprise of the development team, the historian agreed that what the students were doing was very interesting and creative, but that they were *not* "doing history." The project came to a halt. The curriculum project team had mistaken the activities that many historians do to be synonymous with "doing history." We wondered if WEE Science could avoid this trap.

EXPLORING

Over a period of several months, three of us (two professors and one graduate student) used our research time each week to wonder, challenge each other's wonderments, reframe them, and venture into new ones. We had the feeling of following an exciting direction. The wonderments that led to WEE Science were tenacious, and we continued to feel good about pursuing them. Eventually, we moved into another stage of exploration, feasibility testing.

Science Books--Basals and Trade

In this feasibility testing stage, we were concerned about the science books that had prompted some of our wonderments. For those of you who are unfamiliar with school materials, there are several categories of books that students use in school. One category is often referred to as *basals*. Basals are concentrated prose versions of content area information, such as math, science, social studies, and health, which are ranked according to difficulty of content and prose. Books in a basal series sometimes span the age range from kindergarten to twelfth grade. When students refer to their science book, they are probably referring to a science basal, one that is similar to the one used last year, but which probably covers different topics and is written in more difficult prose.

The science books we were wondering about were those in another category, often referred to as science trade books--books written with the explicit purpose of explaining a particular, rather focused science topic (relative to the topics covered in basals), for example, shadows, black holes, paramecia, or telescopes. The prose in tradebooks is typically inspired and adjusted to the reading skills and strategies of an age range of readers. The graphics are delightful, and the countenance of most trade books is very compelling. These impressions were partially confirmed by data that we collected later in our explorations.

Were There Enough Good Trade Books?

Our first feasibility inquiry was directed at the diversity of topics covered by tradebooks. We were familiar with the several hundred that our own children had experienced and those that we had casually noticed in the classrooms we had visited, but was there an abundance of good books? Our inquiry took us to the local public library--one that makes a point of catering to the interests of all readers, but to young ones in particular. There were several thousand science tradebooks on the library shelves, all in the age and topic ranges in which we were interested.

Our inquiry strategy was to pull from the shelves books that seemed directed at the fifth-grade reading and interest level and to ask questions such as: Is this interesting? Does it make us wonder about science things? Do we want to talk about these wonderments with our friends? This first feasibility test was a success. We found that there was a multitude of available trade books--books that were well-written and illustrated, and most important, seemed to prompt wonderments.

How Affordable Were Science Tradebooks?

Another feasibility quest did not meet with success. Our original wonderments included the idea that we would have a small group of students all reading the same tradebook--somewhat similar to the way that several scientists might read the same article in the newest issue of *Science* magazine. To have a group of students reading the same book required having multiple copies of the same book. Most libraries, especially school libraries, seldom have multiple copies; sometimes two copies, but rarely more than that. The possibility that we would have to purchase multiple copies made us nervous, particularly because we had little funding.

So, we investigated the local book stores to determine the availability and cost of trade books. We were excited about the new trade books that were currently being displayed, but were terribly dismayed at the price tags attached to most of them. Few tradebooks cost less than $10, and many ran as high as $30 or more. Our poorly funded project was not likely to survive very long at the experimental stage if rather large expenditures were attached to each implementation--not to mention how difficult it would be for schools to use WEE Science under such expensive conditions. We needed to rethink the use of trade books.

Playing the Role of Fifth-Grade Students

Not to be defeated by the cost of tradebooks, we pursued another tactic. Instead of having a group of students all reading the same tradebook, we decided to try having each student read a different one, but all books would be on the same topic, such as birds, rain forests, microbiology, mammals, or forces that shape the earth. The diversity of topics and abundance of titles found on our visits to libraries and book stores suggested that this approach would work. To test this idea, we collected three or four books on ecology and on mammals. We role-played fifth graders by reading the books and wondering out loud to each other. Some of our wonderments were bizarre, others insightful, and the variety was pleasing. Could we use any of these wonderments as a theme for exploration?

A natural next step was to plan an exploration: We were eager to collect samples of local ground water and test it for acidity, build bluebird houses, find out more about the disappearing rain forest, and send for more information about irrigation projects. The leap from wondering to exploring was a small, natural one for us--would it be so for fifth graders?

At about this time in the development of WEE Science, a fifth-grade teacher joined the research and development team. Given only a brief introduction to our ideas, she was invited to wonder and explore with us. We chose tradebooks on another topic, and the process unfolded again. The teacher appeared to become intrigued and enthusiastic about the process.

Designing The Student Notebook

We made the decision to implement WEE Science with real fifth graders--no more facsimiles. Before that, however, we needed to design a student notebook. Our teacher thought that a notebook would aid the students' understanding of the process. As it happened, designing the notebook helped to solidify our understanding, as well. One of us drafted the various notebook pages (shown in Appendix A), and the team members reacted, interacted, modified, and practiced filling in the information required on the notebook pages.

Designing the notebook also encouraged us to settle on the name of the technique, WEE Science. WEE Science is more than just an acronym for Wondering-Exploring-Explaining, it is "we" as in "us," a community working together to ponder, explore, and discuss scientific questions and procedures, just as professional scientists do. Finally, for the students who participate in WEE Science, each step, exploration, or preparation toward an explanation is but a "tiny" step toward a new understanding of ourselves and our environment. Thus, the name WEE Science stuck.

Pilot Testing WEE Science with Fifth Graders

We conducted two pilot activities about a year apart. We will discuss the two of them in this same section as they were very similar, while still emphasizing those areas where the pilots differed. The same agenda, instructions, and student notebook were used in both sites, and we used video cameras and audio recorders to record as much of the transaction as possible. The major difference in procedures was that Site Two incorporated the use of a pre-project questionnaire to assess students' attitudes and preferences about science and science topics. The students in Site Two also prepared a written essay at the end of the project--which was not required of students at Site One.

The fifth-grade teacher who joined the team later nonetheless contributed to virtually all phases of the development activities, and WEE Science was tested first in her classroom. She was an experienced teacher in a small community where education was valued highly and where teachers were actively appreciated by parents. There were 21 Caucasian students in the class, one of whom was a mainstreamed student with a mild learning disability.

A second site of fifth graders was chosen from a fine arts magnet school in a small midwestern city. There were 23 students in the class, 9 girls and 14 boys. The racial mix was 11 Caucasian children, 8 Africans and African-Americans, and four Asians and Pacific Islanders. The class included 1 mainstreamed student (behavioral disorder) and 5 economically disadvantaged (free-lunch program) children. The teacher had approximately 12 years experience in the classroom, but was unfamiliar with the WEE Science program before the initial contact by a graduate assistant who coordinated WEE Science with the teacher. This graduate assistant was not on the original design team, but learned about WEE Science, primarily by reviewing the videotapes from the first pilot.

Day 1

We began with a general introduction to WEE Science, giving the fifth-grade students an overview of the project, its purpose, and the importance of their role and participation. In one site, the teacher had prepared a large bulletin board, as part of the introduction package, using a "scientist as detective" metaphor. The three steps to being a successful detective were, appropriately enough, wondering, exploring and explaining.

Teaching Students to Wonder

We then conducted a "modeling of wondering" session (e.g., two members of our team sat in front of the students with a couple of tradebooks and modeled wondering). It was not a rehearsed scenario, but one that flowed from our experiences and the ideas in the text we were examining. The modeling was followed by a question-and-answer period. Next, the students practiced wondering, using a photocopied sample reading passage entitled, "How to Build an Ant Village," and then filled out sample wondering logs. The teacher collected the logs and shared some of the practice "wonderments" with the entire class.

Each student then chose a science trade book from among the many that the classroom teacher and school librarian had previously selected and brought to the classroom. The students were divided into interest groups based on the subject of their chosen trade book--space, microbiology, etc.--and then used their trade books to begin wondering. The students were encouraged to share these wonderings with their small groups of 4, 5, or 6 students. They talked among themselves and asked questions. At the close of the session, the students were encouraged to take their books home and continue wondering with their friends and family members.

Day 2

The second day began with a review of wondering followed by the distribution of the science notebooks. After receiving comments and/or fielding questions of clarification about their wonderments from their peers, the students chose one wonderment to explore and explain, and formulated it into a researchable question, which was recorded in the science notebook. A sample of some of the wonderments included the following:

- Marissa chose a book on glaciers and wondered how ice turns blue, where glaciers form, and how they get so big.
- Colin read a book on caves and wondered how caves are formed, why people go cave exploring, how much gold can be dug in a day, and how stalactites are formed.
- Mandy selected a book on astronomy and wondered how the author learned about telescopes, how telescopes are made, what "the invisible universe" means, and what a cosmos is.
- Joel read a book on rainforests and wondered where they are located, how they can be saved, what kinds of animals live in rainforests, and why plants grow so large in the environment.

To get an idea of how well students wondered, we looked at the numbers of wonderments per student. We found that there were 6.8 wonderments per student in pilot 1. Some students had as many as 10 wonderments, some as few as 3.

During the wonderments class time students were observed to be actively engaged in their own and others' wonderings. They browsed through their books, exhibiting looks of consternation, deep thought, puzzlement and understanding; showing each other pictures and reading interesting text aloud. They talked among themselves, filled in their Wonderment Logs, and moved freely among groups, asking questions and making suggestions. Students were observed standing over their desks, leaning in toward a peer's book as a picture was being shown, putting their heads together in the center of the desk cluster, asking questions, and discussing their ideas both among themselves and with the circulating adults. In all, it was a very book-directed environment, with the books serving as a vehicle for both individual and collective activity.

Turning Wonderments into Researchable Questions.

We also were impressed at how well the students were able to create researchable questions. The scope of the researchable questions had to be limited by the constraints of classroom time (1 or 2 days), supplies (what was already available or could be made available very quickly), and space (generally a desktop, section of a counter in the classroom, the floor, the school grounds or possibly, community resources). Thus, the students had to choose a wonderment that was not only interesting, but also met these criteria.

Assigning Group Roles

Each group was asked to assign roles or responsibilities to its members. These roles were explained, and students had no trouble volunteering for them:

1. Project manager--keeps order within the group and encourages students to work cooperatively

2. Resources coordinator--organizes and looks after the groups equipment

3. Data recorder--writes down required information for the group

4. Communicator--acts as the liaison between group and teacher and other groups.

Teaching Students to Explore

The exploring phase began with a discussion of the purpose of exploring and some examples to help students understand and determine their prior knowledge. This prior knowledge, along with the exploration plans, was recorded in the science notebook. The samples and plans were then discussed with the group, and the project manager served as discussion leader. In addition, each group's communicator was to let the teacher know what supplies or resources might be needed to complete the explorations the next day. A notebook page was designed to help the Resources coordinator, who was in charge of the group resource list, with this task.

The next day was devoted entirely to the exploring phase of the program. Students worked individually on their projects and discussed, assisted, and/or participated in each other's projects as required. They were directed to record in their notebooks on the Exploring Log page a chronological listing of their exploring activities.

Exploration included model building, microscope work, observations of various kinds, and experiments, as well as further reading of the tradebooks. Some of the exploring plans chosen included: building models of tornadoes and rainforests; growing bacteria and plants in various environments; collecting samples of fish, bacteria, and petrified wood; observing morning dew and cloud patterns; researching dinosaur sizes in the library; interviewing local weather experts about tornadoes, and about cloud formation and movement; and visiting museums or planetariums. (Some of the activities were to be completed during non-school time.)

We analyzed the strategies that students used to explore and developed the following categories. The number of students choosing each category is presented below. Please note that some students used more than one category.

Reads a book--reads another tradebook or reference book on the topic. Example: A student wonders about black holes and finds more information in the school library.

Consults an expert--locates an expert and asks questions about a topic. Example: A student wonders about "tornado alley" and talks with the local TV weather person.

Consults/visits a museum or other collections of organized objects--goes to a local museum. Example: A student wonders about the size of dinosaur parts, such as teeth and wings, and goes to the natural history museum.

Collects objects from the field--uses the local school yards, playgrounds, parks, woods, and ponds to locate objects that can be collected, preserved, categorized, and analyzed. Example: A student wonders about the effects of acid rain on surface water and collects water samples from local streams and ponds to study.

Makes observations in the field--uses naturally occurring phenomena as objects for observations. Example: A student wonders about the ways that moons, planets, and stars move, so she sketches (or photographs) the patterns of heavenly bodies on several successive nights/weekends.

Builds a model--constructs and operates a model of objects or processes that are too small, big, complicated, infrequently occurring, or expensive for classroom occupation. Example: A student wonders how the water cycle works, so he uses the plans in a science textbook to build an apparatus using materials such as an aquarium, Saran Wrap, and plants.

Conducts an experiment--Conducts an experiment that demonstrates or proves the effects of one variable on another. Example: A student wonders how well disinfectants will kill bacteria, so she conducts an experiment that demonstrates how well various disinfectants inhibit the growth of bacteria on slices of raw potatoes.

Many students were able to employ multiple and varied strategies. For example, some students consulted another book before talking with an expert or conducting an experiment. Other students talked with an expert before building a model. Our impressions are that the students who spent more time consulting books prior to using other strategies developed more informed and successful projects than the students who progressed directly to model building or experimenting. See MacDonell (1993) for a detailed discussion of this proposition.

Teaching Students to Explain

As with the two previous phases, the classroom teacher presented an explanation of the explaining process and gave students an opportunity for questions and discussion. Students were instructed to complete the Explaining Summaries page--a synopsis of the actions they took, their discoveries, and suggestions for further explorations--and the Explaining Plans page--an outline of their explanation and a presentation plan, including an estimate of its length and a list of necessary materials--in their notebooks.

On the explaining day, each group member explained to their group colleagues, the first of their two audiences, the results of their WEE Science project. The purpose of this first presentation was to further organize and clarify their efforts. They used models, demonstrations, posters, and their books to aid in their presentations, which were similar to a "Show and Tell" time with the added dimension that the claims, tenets, logic, and/or conclusions that the students presented were subjected to the group's scrutiny.

Presentations to a larger audience (a combination of two smaller groups totaling about 8 students) were made on the following day. In most cases, a great deal of discussion and dialogue between presenter and audience took place. Students opted to use a variety of aids when explaining their projects. Sometimes they simply reenacted their project. For an example, one student hooked up wires to light bulbs. To aid their explanations others employed models or manipulanda to aid their explanations such as facsimiles of a volcano, tornado or black holes, made from plaster of paris, sticks, heat sources, *papier mache*, and flashlights. In a similar vein, a few students relied heavily on their tradebooks, or other books which they located in a library search, as a source of photographs, charts, and drawings. Finally, many students constructed their own drawings, charts, diagrams, and other graphics to make their points clear.

Our impressions of the explanations--those to the small group of 4 or 5 students and to the combined groups of 8 or so students--are that they were as diverse as with a classroom of adults. Some of the students took a very formal approach to the task, and in one case, admonished the other students to "please be a good audience." Other students approached the task in a shy, unpretentious manner and simply read a prepared report based on information from the Explaining Summary page (See Appendix) in their notebook where we asked the students to summarize the actions, the results, and the remaining wonderments associated with the project.

Evaluation Day

On the last day of the program, the students were asked to participate in a post-project self-assessment and project assessment quesionnaire. Students were given an opportunity to critique their WEE Science experience and summarize the new science they learned as a result of participating in it.

Part I of this questionnaire asked students to "Expiain at least five important things you learned in the WEE Science project." This provided a record of student learning claims that could then be translated into a measure of WEE Science's cognitive and affective effect. These statements were divided into three general categories based on the type of knowledge they represented: (a) Declarative (e.g., "I learned about. . . " or "I learned that. . . "), Procedural (e.g., "I learned how. . . "), and (c) Affective (e.g., "I felt . . . " or "I liked. . . ").

Results showed that students from both pilot studies made a total of 177 declarative knowledge claims. 17 procedural knowledge claims, and 16 affective claims. We estimate that approximately 20% of these claims are based on the students' own projects, 10% on another students', and the remaining 70% are transcendent of a specific one, such as, "I learned that you don't always get what you want the first time."

Parts II and III of the questionnaire were also of interest, as they provided a valuable student assessment of WEE Science as a learning technique. In part II, students were asked to name the "most fun" and "worst" parts of WEE Science. Seventy percent claimed "exploring" was their favorite part, 10% liked "wondering" and "working in groups" best. To the converse question, "What were the worst parts of WEE Science," approximately 50% wrote "nothing," and 50% said they did not like explaining or the video cameras very much.

Part III of the questionnaire measured students' levels of enjoyment for several of the specific WEE Science activities. Students were asked to rate these activities on a 4-point scale: hated it, disliked it, enjoyed it some, enjoyed it very much. The results are as follows on a scale from 1 to 4, with 4 representing the most enjoyment.

Avg. Index		How much did you enjoy:
3.1	1.	reading the book?
3.1	2.	writing down and talking about your wonderment?
3.4	3.	planning for and exploring?
2.9	4.	planning for and explaining?
2.9	5.	writing the summary of your WEE Science experience?
3.6	6.	working in groups?

We analyzed the questionnaire data from both pilots separately, but the results were very similar so we presented them as a total. These results are encouraging in that the mean ratings are well into the positive range of enjoyment. However, about 20% of the students indicated that they did not like at least some of these activities. We are not sure whether these students disliking some of the activities are the same ones who do not like most school activities, or whether there was something specific about WEE Science that they did not like.

Part III also includes students' comments on their communication with family members during their projects. These students indicated that they talked with someone in their family about the science project an average of 3.0 times. There were only 2 students who indicated that they did not talk with their family. We also asked them to rate how much they enjoyed talking with their family about WEE Science; on a scale from 1 to 4, the mean rating was 3.27, a rather high index.

PART V: EXPLAINING

In the introduction, we referred to this report as a part of our explaining. Still in a team format, we generated and computed the ideas for this document. Our plans are to make this one rather detailed and to prepare a more streamlined one for the audience of science educators, whom we also want to reach.

The Show and Tell Seminar at The Center for the Study of Reading

We used an annual event at the Center for the Study of Reading as the first occasion to present our findings from the two pilot studies. The audience was 40 or so educational researchers, graduate students and teachers who spent 2 days reviewing the research and development activities of the laboratory. Each "act" had only 10 minutes on the program. We opted to give a short oral description of the development of the WEE Science ideas, distribute a copy of the student notebook to each seminar participant, and show a carefully edited 7-minute videotape. The videotape featured a series of short vignettes of students from the two pilot studies who were wondering, exploring, and explaining.

Presentation to a Graduate Course in Science Education Methods

One of the visitors to the exploring day of the second pilot study was a university faculty member who was interested in science education. In a subsequent semester, he asked us as developers of the WEE Science program to come to his course (Theory and Practicum in Science) and present a workshop on the program.

This afforded us an opportunity to give yet another presentation on the program. To prepare for this presentation, we followed somewhat of the same procedure we had for the first pilot study:

1. We reviewed all that had transpired regarding the program to date.

2. We wondered what we should have the students do at the workshop and how we should explain to them.

3. We sought out information on our audience--numbers, level of schooling, interests, occupations.

4. We went to the library and picked out trade books for the students to use in the class.

5. We developed a questionnaire to give to the participants after the workshop.

6. We prepared an explaining form--an outline if you will--of what we would be doing in the workshop.

Our outline included a description of the program, a summary of the findings, and a brief videotape of the actual pilot studies. We discovered that as an assignment, the class had already read one of the researcher's master's thesis on the topic; this alleviated some of the difficulties of having too much to explain in too short a time.

The night of the presentation, we discussed the program and showed the video. The students seemed to appreciate the brief summary and the video. They were a bit surprised when we requested that: (a) each one of them choose a trade book from among the 20 or so we had checked out of the public library and brought into the classroom; (b) arrange themselves into groups according to topic; and (c) begin wondering. Books were chosen, groups formed, and tentative wonderings began. We wandered from group to group, encouraging and supporting, and saying, "Yes, indeed, it certainly is OK to wonder about x." The class had formed itself into three groups: an animal group, a space group, and an earth science group. What began as a tentative struggle with wonderments soon became an animated discussion among group members as the participants began to share "things I have always wondered about" their topics. We also encouraged them to begin thinking about how they might explore their favorite wonderment.

After about 20 or 30 minutes, we reconvened the whole group to share wonderments. We asked the students to discuss a couple of their wonderments and to reveal the one they chose for exploration. We asked the other class members to share any insights, thoughts, or suggestions they might have for the exploring plan that was being proposed.

We were delighted at the enthusiasm, interest, and sincerity with which these participants shared wonderments and plans, and offered suggestions. Each person, from traditional graduate students to a high school principal, exhibited a great deal of delight at being able to plan a method for investigating an authentic question that had been proposed. For example, one participant said that he had always wondered "how birds fly or how wings work." Yet, another participant had had experience with clipping a pet parakeet's wings. She offered suggestions and volunteered her bird to the "wonderer" as a potential "subject" for investigation the next time the bird had his wings clipped. What would happen if only the feathers of one wing were clipped? What would happen if there were only a few on each wing? Her suggestions were a very "doable" set of questions in an otherwise broad wonderment.

Another participant had always wondered "what happens to the stuff that got picked up and carried by the glaciers." She was directed to a park in her area, Moraine View State Park, which has evidence of "the stuff that the glaciers had left" behind when they retreated from the area.

The time flew by quickly--too quickly--but the participants seemed to have developed an idea not only of how WEE Science works logistically, but how interesting, enjoyable, and "scientific" it can be. One wonderer reported that he would worry about his wonderment all the way home--and he lived 50 miles away--and probably until he could find a satisfactory answer.

As a final request, we asked them to fill out a questionnaire--the results of which follow. The students responded to a variety of items using a scale from 1 to 10. The first 5 scales had to do with the tradebooks the students used in their wondering and concerned their clarity, how interesting they were, their scientific accuracy and their appropriateness for fifth graders. The mean rating from 10 raters on these 5 scales was 7.4 out of 10 possible--a rather strong endorsement of our positive impressions of tradebooks.

We asked another set of questions about the appropriateness of using WEE Science in the fifth-grade curriculum for the purposes listed below. High ratings based on a scale from 1 to 10 indicated that WEE Science was most appropriate.

		Ave. Appropriateness Index
1.	To introduce a science unit (e.g., space, invertebrates)	8.1
2.	To follow up a science unit	8.3
3.	To replace other ways of teaching a science unit	7.3
4.	To replace a science fair	8.0
5.	To introduce a science fair	8.7

Once again, the ratings showed a strong endorsement for WEE Science--which appears to have a place in the classroom curriculum. The lowest rating of "7.3" seemed to indicate that WEE Science should be thought of as an elaboration of the regular science program--not a replacement. This interpretation is consistent with our intentions for the position of WEE Science in the curriculum.

A third set of questions requested the raters' overall impression of WEE Science on the following dimensions: detrimental-helpful (9.7), boring-interesting (9.5), expensive-inexpensive (8.4), unscientific-scientific (8.6), inefficient-efficient (8.5), and ineffective-effective (8.9). The indices are the average ratings on a scale from 1 to 10. Once again these ratios support the notion that WEE Science is a very attractive program.

Our final impression was that this explaining phase of our WEE Science was fulfilling and afforded us many opportunities to learn more about our project, to expand our wonderments about it, and to continue exploring and explaining it to others.

PART VI: WHAT WE ARE STILL WONDERING ABOUT

We encountered some problems during the pilot studies which created another round of wondering. What follows are the major categories of wonderments and our thoughts about them.

1. We are still wondering about how to evaluate the students' work.

This was not really a problem for us during the pilot studies, as we relied on actual classroom observations and notebook assessments to guide our thinking about the successes of and possible problems with the project. In addition, we had two video tapes of almost every classroom component of the WEE Science project and the questionnaires and post-project assessments to analyze and discuss. Thus our purposes for assessment and evaluation of the project were met.

We are aware, however, that classroom teachers will have other purposes for assessments and evaluations. Thus, we would like to offer some suggestions as to how WEE Science could be or might be evaluated in a regular classroom setting. Please be advised that these suggestions are, at this stage, wonderments on our par--discussed, contemplated, and in some cases planned, but not at this time explored.

What are some of the purposes teachers might find for assessment or evaluation? Teachers might need to:

1. assign a grade for a student's report card,

2. communicate with parents about a student's progress,

3. provide specific feedback so that the student knows how to progress,

4. determine what and how much a student knows, can do and feels (so that change can be documented).

In addition to the above individual student-centered purposes, the teacher might want to:

5. use information from the program to make instructional decisions about what to do next,

6. compare what the students learned using the WEE Science technique with information from other programs,

7. assess the effectiveness of the materials, books, etc. that were used.

To get an informed assessment of a student's learning and achievement, a variety of indices is important. One of the very positive aspects of the WEE Science program is that the various phases of the program lend themselves readily to several types of assessments at many different points in the program. For example, there are numerous products that might be evaluated: the notebooks as a whole or various components of them, such as the exploring plan or the explaining plan. Exploring plans in the notebooks, for example, could be judged with an eye to their completeness and feasibility (could someone else reconstruct the project?--a standard used in scientific reporting), as could explaining plans. The outcomes of the exploring plan, models, charts or diagrams, and the aids used in explaining, such as reports and photographs, offer other sorts of products for assessment. The presentation itself could be thought of as a product and scored using a multiple scale of performance aids (visuals, models) content (was relevant information given, were concepts clarified, etc.). In addition, the audience (other students, teachers, parents, or possibly visiting experts) could be asked to help rate or judge the performance.

There are also attitudes that could be observed and assessed: supportiveness, cheerfulness, work habits, social relationships, and concern for others, to mention a few. In addition, the students themselves could be encouraged to become thoughtful respondents and judges of their own attitudes and work habits as well as those of their peers.

As is the case in other programs, the teacher need not be tied into judging only mastery of an antecedently determined content, but would have the opportunity to choose the content that would most naturally spring from the learning activities being engaged in by the students. It would even be possible to assemble some sort of paper and pencil or oral test for the whole class, where the teacher asks questions based upon the material that has been presented by each student. While listening to each presentation, the teacher could take notes on the content and then "test" the whole class to see if students were getting out of the presentation what s/he was getting out of it or else ask more open-ended questions to find out what they were getting out of it; these could be either written or oral tests.

Eventually, all of the WEE Science materials from one student could be assembled into a science portfolio complete with materials from other science experiences, and successive WEE Science interactions could be added to a growing portfolio which would give the learner a personal record of science learning growth. This would present an excellent opportunity for the teacher to share the portfolio with the parents, provide feedback to the students, document how much a student has changed and/or learned, as well as give the teacher a tool for making instructional decisions, and evaluating the program success as a whole (see Sunstein & Graves, 1992).

2. We wondered what to do about students' misconceptions. One of our biggest concerns about WEE Science is with the number of science misconceptions (Clement, 1982) that students listed in their final evaluations. Many of the misconceptions seemed to have been brought to the project from the students' past experiences, but others were probably learned in the course of the project. For example, one student concluded that "everything green has dew on it every morning."

It is important to consider the possibility that WEE Science reveals misconceptions more graphically than other forms of science instruction, and they may thus appear to be more prevalent; however, we propose that misconceptions are indigenous to learning--perhaps, particularly in science--and better ways of revealing them are needed. We suspect that "revelation is prelude to enlightenment," a suspicion that has some research underpinning (Mayer, 1987).

We were also impressed with the number of intriguing topics, issues, and questions that emanated from the experiences that students shared with the teacher and the other students. These topics, issues, and questions could become the basis for further instruction in science and other areas such as social studies. One example is the use of animal subjects in research, an issue that emerged during our pilot when some students balked at the idea of submerging live minnows in oily water.

Some have suggested that a child working through naive conceptions mirrors the path that humankind has trekked on its journey to the current scientific understanding--in other words "the historical development of adult thinking in the natural sciences" (Driver & Easley, 1978, p. 70). In fact, Licht and Thijs (1990) state that, "we would suggest that students who demonstrate alternative ideas in a coherent way over several contexts already show the reasoning ability demanded for the acceptance of the scientific conceptions. In this way, a coherent alternative idea can be seen as an intermediate step in the acceptance of a scientific idea" (p. 414). These ideas temper, somewhat, our concern about scientist misconceptions. After all, much of what is known today will become the "misconceptions" of tomorrow.

3. We wondered whether it was possible for the typical classroom teacher to understand and deal with so much science in a concentrated period of time.

Driving this wonderment is the fact that many teachers feel a reluctance to approach science instruction in an open-ended way. Few teachers have a basic grounding in science. What makes us think that teachers with impoverished science backgrounds and attitudinal inhibitions can use WEE Science? While not recommending a limited science preparation, we propose that this program makes use of what knowledge the teachers as well as the students do have and then enables them to explore further. Since the emphasis is on the scientific process and the search for knowledge, a teacher need never feel hesitant to say, "I don't know," or be pressured to give less than helpful answers. After all, a teacher need not accept the role of an expert or the final authority in any content area. A cooperative learning/reciprocal teaching environment makes use of the resources of everyone in the classroom, making it easier for each to perform well.

During the pilots, at least one other person was always present in addition to the classroom teacher, and during the exploring phase of the project two or more other persons were present. A classroom teacher's desire for help during phases of WEE Science could present an opportunity to bring parents and grandparents, observers from local institutions of higher learning, high school helpers and/or other teachers into the classroom.

There were various kinds of resources available in anticipation of some of the types of experiments or displays the students might create. While this list appears rather extensive, it is not as financially prohibitive as might be imagined. These resources were: (a) materials that are usually found in a classroom: rubber bands, tape, jars, construction paper, colored pencils, rulers, poster board; (b) materials that might be found in a well-stocked science room: electrical components such as switches, sockets, wires, batteries, and items such as microscopes, lights, and bunsen burners; (c) materials from the field or from home: grass seed, motor oil, pond water samples, bits of wood, and shoe boxes; and (d) materials that might need to be borrowed: litmus paper, petri dishes, and chemicals.

In addition, we were impressed by the number of "teachable moments" made available to the teachers--those moments when a student asked a very good question about some phase of the WEE Science project or appeared to be baffled, halting, or uncertain. In all phases of the project, students asked very insightful questions about wonderments, procedures, science facts and principles, and planning. Typically, we did not answer these questions directly; instead, we suggested that the students refer their questions to other group members, or we gave them suggestions about where/how they could find possible answers.

4. We wondered why some students were having trouble with some of the notebooks pages. Some were unable to organize their thoughts and put them into readable form, some didn't seem to understand why they were filling in the pages--particularly the Exploring Log page and the Explaining Plans page. At certain points, relevant discussions pertaining to notebook activities and instructions for completion were aided by the teacher. On Day 4, for instance, she opened the session by asking students to explain the purpose of the Exploring Log. In a dialogue with one student, it was agreed that the log's purpose was "to store information that you've found out as you're exploring, as well as how and when you found out."

5. We wondered where WEE Science would fit best in the curriculum. As we are envisioning WEE Science, the classroom teacher plays an important, flexible role. The teacher has the option/responsibility for decision making in various areas. In a very real sense, the teachers in a WEE Science environment are choosing not only the process but also the content of the instruction. This is done by choosing the books that students will be using. If the teacher wants to enlighten the students about space, for example, all of the books s/he chooses could be on the topic of space. If a unit on climates is desired, all of the books could be about different climates in this country or any other country. By the same token, the teacher could choose where in the unit on space or climates, for instance, the WEE Science program would be used. Some teachers might want to use WEE Science to introduce the unit. Others might use it to replace a textbook unit. Still others might find a use for WEE Science at the end of a unit.

We are wondering if WEE Science could be used as an introduction to a science fair to get the students to begin thinking about the kinds of projects that might be suitable for a science fair. A WEE Science unit would offer the students a unique opportunity to practice or try out (explore) some ideas (wonderments) before having to put them on display at a science fair. Another option might be to have WEE Science replace a science fair entirely. Given the way science fairs currently are formulated, many students are unable or unwilling to participate in them. Some students find them too competitive. Some students do not have the resources--financial, logistical, etc.--to plan, design and exhibit a project. Some students would like to participate but have little experience in coming up with a topic and little confidence in their ability to do so. In the Wee Science program the stress on an individual student is lessened because WEE Science is not competitive in any sense. In addition, the students are encouraged to work in groups so that any one student's ideas can be enhanced by the knowledge and experience of the others. An advantage of the WEE Science program is that it combines many of the benefits of a science fair--independently generated student work, creativity, self-motivation, and initiative, to name a few--with few of the above-mentioned disadvantages of a science fair.

There are other curricular questions we are wondering about. WEE Science was originally conceived out of our ideas about introducing more authentic reading into the content areas--science was chosen as a first step--but, would it be possible to use the WEE Science technique in other content areas--social studies and English, for example? Are there enough tradebooks on these topics to generate the wonderments to drive explorations? Are there exploration possibilities for these content areas? We are also wondering if content area combinations are not possible--combining WEE Science and social studies, for example. Because of the emphasis on reading, would it be possible for WEE Science/social studies to replace part of the reading or language arts day?

At what grade level should WEE Science be used? We piloted it in fifth-grade classrooms, but could it be used in the lower grades, middle school, or high school? Several of the participants at one of our presentations asked our opinion about trying WEE Science in the upper grades and expressed a desire to see it happen. Could a high school chemistry class follow the program with some slight modifications? We have thought about the kinds of chemistry books and journals that are available for use in the high school classrooms and are eager to explore this possibility.

Another thing we are wondering about is how often during the year a teacher might want to use WEE Science. This would depend primarily on the purpose for which it was being used but, again, this is another decision that would be in the hands of the classroom teacher.

We are not sure at this time how these options or ideas might work, but we are "wondering" about them and may come up with an exploring plan for some of them in the near future.

8. We are wondering about the possible compatibilities of WEE Science within the context of the national current emphasis on literacy. We are tempted to claim that reading and writing problems have at least a partial origin in "interestingness" of materials that students read and topics about which they write. Furthermore, WEE Science students have the opportunity to become the transitory and local "expert" on an issue or topic. Recall that students select books from a number provided and create wonderments, questions of personal interest, contextualized of course within some general topic. Interests breed expertise and expertise breeds interests. In WEE Science, the students can respond to the mystery of what they do not know, or, on other occasions, nestle into the comfort of expertise. Either provides a context where literacy can develop.

We think that the integration of reading and writing within WEE Science could evoke considerable progress in literacy. Permit one anecdote. Years ago, one of the authors had a seventh-grade student whose reading was well below grade level, who simply would not read and who was a reluctant, poor, and unenthusiastic writer. On a local archaeological field trip the author, who was then the teacher, mentioned the age of an artifact. "How do you know how old that is?" asked the student. Several dating techniques were briefly discussed, and a few days later the student was given a bibliography on dating techniques. The student quickly became an "expert," read a great deal, and wrote several very good, short papers on the topic. For later writing assignments, there was little whining about not knowing what to write about. This student made a great deal of progress in literacy during the remainder of the year.

9. Finally, we are wondering about the reception of WEE Science in a science education community, in which, while there is little consensus, many members place extraordinary emphasis on "hands-on" activities. WEE Science, after all, begins with books, and a frequent method of exploration chosen during our two trials was reading more books. Without apology, we think of science as primarily "minds-on" rather than merely "hands-on" and judge WEE Science to be effective in using books to attain the activation of mind in science. We do not necessarily see WEE Science as the total science curriculum; but we do see the primary role of the book as a beginning point in WEE Science, and hope the community can share that vision.

PART VII: CONCLUSION

We conducted two pilot studies of a new science program we call WEE Science. The studies were conducted in fifth-grade classrooms with the cooperation and participation of the classroom teachers. The program encouraged the students to choose a science trade book from among the many that had been selected and brought to the classroom by the teacher. Following the trade book selection, the students were to form groups based on the topics of the books, and ask questions (Wondering) about the content. After choosing one of the wonderments to pursue further, the students were to formulate a plan for investigating it and then follow through with the plan (Exploring). This resulted in classrooms in which groups of 2 or more students were each doing a different hands-on science activity. The students were then to explain (Explaining) to a group of their peers what they had wondered and what and how they had explored. The pilots lasted for 7 days in one of the classrooms and 9 days in the other. The students' wonderments, activities, plans, and explanations were recorded in a science notebook that had been designed for that purpose. In addition, the classrooms were videotaped while WEE Science was in progress. We analyzed the notebooks and the videotapes to help us with our own explorations and explanations of WEE Science.

We were very pleased with the initial pilot implementation. Particularly impressive were: the excitement that students showed in choosing and reading their trade books, their success at generating and explaining wonderments, the enthusiasm and creativity they showed in directing their own explorations, and the thoughtfulness and carefulness with which they composed the presentations of their projects. We were also pleased with the amount and type of science ideas that students reported learning from their own projects, as well as from the diverse projects they saw and heard about from the other students in the classroom.

Other observations indicated that the students needed more instruction, modeling, and practice to improve in some areas, including: formulating researchable questions, planning an exploration and presentation, and writing exploratory steps in their logs. Our explorations in this area were fueled by the idea that neither "canned activities" nor textbook presentations of science concepts/ideas/facts/data "connect" to the students' world, nor are they often situated in any way that makes sense to young students. The WEE Science program attempts to eliminate that problem by encouraging the students to interact with the text in their own way. Thus, the students are able to choose their own type of involvement, witness how others in the group (and eventually, possibly, in the entire class) have chosen to become involved, and also, through the text, are given opportunities or challenges to deal with concepts in other ways. The text, then, is not presented as an absolute authority, or the final word. The students are encouraged to hunt for other tools--other books, experts, museums, diagrams--and then to distill all of these inputs into an explanation for the entire group. The students are doing science--asking questions, formulating hypotheses, generating explanations, testing them out on each other in their classroom--much the way scientists do. They are moving from the abstractions presented in a tradebook to the personally and socially constructed concretions of their daily lives. The WEE Science program attempts to encourage students to take a critical stance, to ask questions, to analyze the answers, to promote Minds-on-Science.

The goals and expectations of the program are based on those recommended in *Science for All Americans* for the development of a scientifically literate population. An understanding of the scientific process and the attitudes necessary for doing "good science" are elementary if we are to become a nation of science literates. WEE Science incorporates the best attributes of good reading instruction with the learning of good science.

We have continued our own wonderments of this project and are convinced that there are several areas that warrant further explorations. These include explorations in various ways to assess the students' learning in science as a result of participating in WEE Science and what to do about misconceptions that might be formed as a result of doing science this way. We also wonder if classroom teachers will feel equipped to handle this program--the open-ended nature of it as well as the considerable commotion that can result when many students are doing different projects. We are also questioning how to manage the phases of the program that seem most problematic for the students, particularly the aspects of planning and recording in the notebook. And finally, we are curious about the spots or points in the curriculum where WEE Science might be of the most benefit. We have suggested some of our ideas on these topics to our peers in various settings and in this piece. And we intend to continue the search for more ideas and opportunities for explaining them in the future.

References

Applebee, A. N. (1984). *Contents for learning to write: Studies of secondary school instruction*. Norwood, NJ: Ablex.

Applebee, A. N., Langer, J. A., & Mullis, I. V. S. (1987). *Learning to be literate in America: Reading, writing, and reasoning. The nation's report card*. Princeton, NJ: Educational Testing Service.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50*, 66-71.

Dewey, J. (1916). *Democracy and education*. New York: Macmillian.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 50*, 61-84.

Edwards, C. H. (1993). *Classroom discipline and management*. New York: Macmillan.

Edwards, C. H., & Fisher, R. L. (1977). *Teaching elementary science: A competency-based approach*. New York: Praeger.

Goodlad, J. I. (1983). *A place called school: Prospects for the future*. New York : McGraw-Hill.

Herber, H. L. (1978). *Teaching reading in the content areas*. Englewood Cliffs, NJ: Prentice-Hall.

Kennedy, B. (1985). Writing letters to learn math. *Learning, 13*, 58-61.

Kintsch, W. (1977). On comprehending stories. In M. A. Just & P. A. Carpenter (Eds.), *Cognitive processes in comprehension* (pp. 33-62). Hillsdale, NJ: Erlbaum.

Knorr-Cetina, K. (1981). *The manufacture of knowledge: An essay on the constructivist and contextual nature of science*. Oxford: Pergamon Press.

Latour, B., & Woolgar, S. (1979). *Laboratory life: The social construction of scientific facts*. Newbury Park, CA: Sage.

Licht, P., & Thijs, G. (1990). Method to trace coherence and persistence of preconceptions. *International Journal of Education, 12*(4), 403-416.

MacDonell, E. S. (1993). *Designing an integrated approach to teaching and learning science: A pilot study of WEE Science*. Unpublished thesis at the University of Illinois, Urbana-Champaign.

Mayer, R. E. (1987). *Educational psychology*. Boston: Little, Brown.

Rutherford, F. J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Slavin, R. E. (1980). Cooperative learning. *Review of Educational Research, 50*, 315-342.

Spargo, E., & Harris, R. (1978). *Reading the content fields*. Providence, RI: Jamestown Publishers.

Sunstein, B. S., & Graves, D. H. (1992). *Portfolio portraits*. Portsmouth, NH: Heinemann.

Tchudi, S. N., & Huerta, M. C. (1983). *Teaching writing in the content areas*. Washington, DC: National Education Association.

Webb, N. M. (1982). Student interaction and learning in small groups. *Review of Educational Research, 52*(3), 421-445.

Authors' Notes

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Appendix A

Selected Pages from the WEE Science Student Notebook used in the Pilot Study

WONDERING

How to wonder with a science book: Start wondering by looking at the cover, the table of contents and flipping through the book. Let the pictures, titles and words catch your attention. After it has your attention, for even a moment, read some of the text and let it tease your imagination. Then, write down your first 'wonderment'. Also, describe what in the book got your attention.

I Wonder (if, how, why, who, what, when, where, whether, which):	**What in the book helped me wonder:**
1	
2	
3	
4	
5	
6	
7	
8	

EXPLORING
Prior Knowledge

What am I going to Explore?

What I Now Know About My Exploration Topic:
(ask family members or friends if you need help remembering)

1.

2.

3.

4.

5.

6.

7.

What Do I think I'll find? Why?

EXPLORING
Plans

How am I going to Explore:

First, I'm going to:

Next, I'm going to:

Then, I'll probably:

Then, I'll probably:

Then, I'll probably:

Finally, I'll:

To Explore like this, I'm going to need these resources:

Each of My Group Members Understands These Plans and Thinks That They Should Be Used: (Data Recorder makes sure that this is done.)

________________________ ________________________

________________________ ________________________

EXPLORING Log

Name: ______________________________

My "Wonderment": ______________________

____

Date/Time	What I Did:	What I Found Out:

EXPLAINING
Summary

The Actions I took were:

I found out that:

I'm still wondering about:

EXPLAINING

Plans

The main thing I found out was:

Other things I found out were:

Who is the Audience for this presentation?

How am I going to Explain these things to the Audience so that they are Clear and Believable?

What Materials am I going to need for this Presentation?

How long is it going to take to get my presentation ready?

Each of My Group Members Understands These Plans and Thinks That They Should Be Used: (Data Recorder makes sure that this is done.)