Third Misconceptions Seminar Proceedings (1993)

Paper Title: **The Development of Earth Concepts**
Author: Maria, Katherine

Abstract: A large body of research has established that children often understand and explain concepts about the earth in ways that are different from scientific explanations. For example, children have been found to believe that the earth is a flat disc or that the earth is round like a ball but we live on the flat part inside the ball (Nussbaum, 1979), that gravity pulls to the "bottom of space" (Sneider & Pulos, 1983), that day and night are caused by the movement of the earth around the sun (Vosniadou, 1992) and that summer is warmer than winter because the earth is closer to the sun (Maria, 1988). Vosniadou (1992) has suggested that as children develop and are exposed to scientific explanations of these phenomena they move from **intuitive** mental models based on their experience and showing no influence from adult scientific models to **synthetic** models that are a combination of intuitive and scientific views. Some children then develop **scientific** models after exposure to current scientific views either incidentally outside of school or through formal instruction, but many retain the intuitive and synthetic models that we characterize as misconceptions even into adulthood. For example, Hazan and Trefil (1991) reported that 21 of 23 graduates interviewed at the 1987 Harvard Commencement had a misconception about the cause of the seasons.

Keywords: Concept Formation,Educational Methods,,Concept Teaching,Misconceptions,Scientific Concepts,Cognitive Dissonance,Change Strategies,Teaching Methods
General School Subject: Earth Science
Specific School Subject: Astronomy
Students: Elementary School

Macintosh File Name: Maria - Earth
Release Date: 12-16-1993 C, 11-6-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

Note Bene: This paper is part of a collection that pioneered the electronic distribution of conference proceedings. Academic livelihood depends upon each person extending integrity beyond self-interest. If you pass this paper on to a colleague, please make sure you pass it on intact. A great deal of effort has been invested in bringing you this proceedings, on the part of the many authors and conference organizers. The original publication of this proceedings was supported by a grant from the National Science Foundation, and the transformation of this collection into a modern format was supported by the Novak-Golton Fund, which is administered by the Department of Education at Cornell University. If you have found this collection to be of value in your work, consider supporting our ability to support you by purchasing a subscription to the collection or joining the Meaningful Learning Research Group.

----- -----

The Development of Earth Concepts

Katherine Maria, College of New Rochelle, U.S.A.

Theoretical Framework/Rationale

A large body of research has established that children often understand and explain concepts about the earth in ways that are different from scientific explanations. For example, children have been found to believe that the earth is a flat disc or that the earth is round like a ball but we live on the flat part inside the ball (Nussbaum, 1979), that gravity pulls to the "bottom of space" (Sneider & Pulos, 1983), that day and night are caused by the movement of the earth around the sun (Vosniadou, 1992) and that summer is warmer than winter because the earth is closer to the sun (Maria, 1988). Vosniadou (1992) has suggested that as children develop and are exposed to scientific explanations of these phenomena they move from **intuitive** mental models based on their experience and showing no influence from adult scientific models to **synthetic** models that are a combination of intuitive and scientific views. Some children then develop **scientific** models after exposure to current scientific views either incidentally outside of school or through formal instruction, but many retain the intuitive and synthetic models that we characterize as misconceptions even into adulthood. For example, Hazan and Trefil (1991) reported that 21 of 23 graduates interviewed at the 1987 Harvard Commencement had a misconception about the cause of the seasons.

Once misconceptions are constructed they prove resistant to change even with carefully planned and intensive instruction. It has been suggested that this is because misconceptions are part of a conceptual ecology that includes affective components and cognitive defense mechanisms (Strike & Posner, 1992). The resistance to instruction of many misconceptions has led to recent calls for investigation of the process by which children construct and maintain their misconceptions (Guzzetti, Snyder, Glass & Gamas, 1993; Strike & Posner, 1992). Although Nussbaum (1979) and Sneider and Pulos (1983) and Vosniadou and her colleagues (Brewere,Hendrich & Vosnaidou, 1988; Vosniadou, 1987, 1989, 1992) did attend to this process by studying different children at different ages, very few studies have traced the process longitudinally with the same children. One case study of a sixth grade boy provided insight into the process by which he maintained and corrected his misconceptions about the shape of the earth and the causes of day and night and the seasons (Gordon, 1992a, 1992b).

The two case studies described in this paper were inspired by the Gordon study and address similar questions, but the subjects of these studies are primary grade children. The questions addressed by these studies are:

1. What misconceptions and/or scientific ideas do the children have about the earth concepts that were the focus of the Gordon study?
2. What seem to be the sources of these ideas?
3. How are these ideas maintained and/or changed after formal instruction?
4. What instructional techniques help the children to correct their misconceptions and/or acquire correct scientific concepts about the earth?

Since these children had had very little formal science instruction and none related to earth concepts before the studies began, identifying the sources of their ideas, though still a very difficult task, seemed more possible than with older children whose experience would be more extensive and varied. If at least some of the sources of the misconceptions and/or scientific ideas that these young children brought to the study could be determined, the study would provide valuable information about the incidental science learning of young children.

On the other hand, the children's knowledge in this area also suggested that at times their first consideration of a particular concept might occur as a result of the investigator's questions. If there was evidence that this was so, then consideration of how the questions the child was asked interacted with other factors such as the understandings and experience the child brought to the task and his/her learning style might well provide information about the process by which misconceptions are generated.

Very few studies in the misconception literature have attempted to provide instruction for primary grade children. One reason for this is that many scientific ideas are considered beyond their understanding (Shayer & Adey, 1981; Schollum & Osborne, 1985). However, Nussbaum (1971) suggested that the appropriate presentation of concepts at an earlier age might prevent later erroneous concepts. A longitudinal study by Novak and Musonda (1991) found that first and second-grade children who received audio-tutorial lessons about matter and energy developed by Novak and his colleagues (Novak, 1972) had more valid conceptions and fewer invalid conceptions twelve years later than an uninstructed group. The instruction in their study included much hands-on manipulation of concrete objects as well as the reading of texts.

The scientific concepts that are the focus of the present study cannot be experienced throught the same type of hands-on activities. We do not feel the earth turning nor see it tilt. However, a study by Nussbaum and Sharoni-Dagan (1981) found that second graders can advance in their understanding of the earth's shape and gravity concepts through individual tutorial sessions. Although hands-on activities with models need to be part of instruction about earth concepts (Vosniadou & Brewer, 1987), for the most part these concepts must be transmitted socially through oral and written language. Thus these concepts are particularly interesting to a reading researcher like myself because investigating appropriate instruction related to them provides me with the opportunity to study the role that written text plays in the process of conceptual change. I was interested in teaching earth concepts to young children because my own previous studies (Maria, 1988; Maria & Hathaway, 1991; Maria & Johnson, 1990; Maria & MacGinitie, 1987) had provided me with first-hand experience of the resistance that middle grade children's misconceptions show to instruction. My previous studies had also suggested that text that discussed and corrected children's misconceptions in addition to providing scientific ideas (**refutation text**) was helpful to the process of conceptual change. In addition, the Maria and Johnson (1990) study demonstrated that providing this information in a narrative was helpful for younger children.

Participants

The subjects of the two case studies are a boy (Charlie, a pseudonym) who was 5 years and 4 months and a girl (Jennifer, a pseudonym) who was 6 years 6 months when the investigation began. During the year and a half that the studies have been conducted up to this point, Charlie has completed first grade and Jennifer has completed second grade.

Both children are the oldest in their families. Charlie has two younger brothers (ages 4 and 1) and a younger sister (age 3). Jennifer has two younger brothers (ages 6 and 2). The children are first cousins who interact often with each other and other members of their extended family including their grandparents and an aunt who teaches second grade.

The children both attended different preschools and now attend two different parochial schools. In addition, both children have attended QUEST, a Saturday program for gifted children conducted by the college where I teach. Charlie has attended 5 five week sessions and Jennifer has attended 3.

Although neither child has been formally identified as gifted, observations by the director of the QUEST program who is an expert in the field of gifted education and the results of the tests described below suggest that both children have above average ability. On the Kaufman Brief Intelligence Test (Kaufman & Kaufman, 1990) administered to the children in March 1992, Charlie scored at the 99.8th percentile and Jennifer scored at the 97th percentile. There was no significant difference between Charlie's scores on the Vocabulary and Matrices subtests, but Jennifer's standard score on the Matrices subtest (137) was 25 points higher than her score on Vocabulary, a difference significant at the .01 level.

In June 1992, testing with the Concept Assessment Kit-Conservation (Goldschmid & Bentler, 1968), placed Charlie at the 90th percentile and Jennifer at the 60th percentile. Both achieved conservation of space, number, substance, continuous quantity and area. In addition, unlike Jennifer, Charlie achieved conservation in length and weight but not in discontinuous quantity.

In May 1993, on the Comprehensive Test of Basic Skills, Fourth Edition, Form A-11 (McGraw-Hill, 1989), Charlie scored at the 91st percentile in total readin, the 68th percentile in total mathematics and the 90th percentile on the total battery. On the same test, Form A-12, Jennifer scored at the 71st percentile in total reading, the 77th percentile in total mathematics and the 75th percentile on the total battery.

Charlie was chosen as a subject for the case study because he had expressed an interest in science since the age of 3 when he watched the Mr. Wizard television program every morning before the rest of the family got up. His parents and other members of the family encouraged his interest so that before the study began Charlie had many science books and toys. Jennifer was selected because neither she nor her family perceived her as having any special interest in science despite her interest in plants and animals. Although her talent in mathematics had been recognized by her family, before the study began she was not being encouraged in the development of this talent but was being guided toward more "feminine" pursuits (e.g. ballet lessons).

Since I am the paternal grandmother of both children, I am definitely a participant observer. Therefore, it seems appropriate to discuss the background I bring to the investigation. I have experience teaching young children since I was a Chapter I reading teacher for 8 years, and am now serving as consultant in two school districts where I work closely with primary grade teachers and children. However, my work with these children involves reading and writing instruction rather than science. My research in the area of misconceptions has prompted me to read extensively in the science education literature on misconceptions. Since I have conducted several studies focusing on the misconception regarding the cause of the seasons (Maria, 1988; Maria & Hathaway, 1991; Maria & Johnson, 1990), I have focused my reading on earth concepts. However, in my own education, my only scientific training was in psychology.

Data Collection/Procedures

I had reservations about using my grandchildren as subjects in a research study. No one it seemed to me is less objective than a grandmother. My colleagues in reading research encouraged me, however, pointing out that as a member of the family I would have access to a richness of data unavailable to anyone outside the family and that family members had been used by other researchers most notably Piaget.

I met with the children approximately every 4 weeks since February 1992. There were 16 hour-long individual sessions with Charlie and 13 with Jennifer. During the summer of 1992, I had 4 sessions with the children together. However, both of the children said the other did not give them a chance to talk, so we went back to individual sessions. The sessions were audiotaped. I listened to the tapes as soon as possible after each session, jotting down notes about the context that would help my graduate assistant in transcribing them. I then checked each transcription against the tape.

In addition to these formal sessions, I saw the children at least once a week with the rest of the family. Anything that occurred relevant to the study at these times was recorded in field notes. I also interviewed Charlie and Jennifer's parents, their aunt, Charlie's kindergarten teacher, and the children's teachers in the QUEST program. On two occasions I observed the children in their science classes at QUEST.

In each session, I interviewed the children about earth science concepts, using questions developed by Klein (1982), Nussbaum (1979), Nussbaum and Novak (1976), Sneider and Pulos (1983) and Vosniadou (1987). I usually only asked a few questions each session, and questions asked in a previous session were often asked again in different situations with different wording.

By the third session with each child, I began to provide instruction related to the questions I was asking. Children's trade books about earth concepts were often used to provide information. For example, in our third session, when I asked Charlie what was above, on the side, and below the earth, I pointed to the picture of the earth in a book he had brought with him (Kitamura, 1989) to help him answer the question. In conjunction with time lines, myths and non fiction tradebooks were also used to help the children see how people's understanding of earth concepts developed over many years. Teaching the history of science, i.e. presenting science as a story, has been suggested as an effective way of presenting scientific ideas and preventing and correcting misconceptions (Duschl, Hamilton & Grandy, 1992). Martin and Miller (1988) and Rutherford (1991) particularly recommended this approach in teaching earth concepts to young children. Books were also used to provide directions for activities and review of information presented orally and through demonstrations. Semantic maps, comparison/contrast charts and comprehension techniques like K-W-L (Ogle, 1986) were used in conjunction with the reading. In several sessions, our purpose for reading was to determine whether the book contained any information that we did not already know.

Models of the earth were used in all the sessions to support oral explanations. They included a standard globe, an inflatable globe with stickers that could be placed on the globe to label locations (Wolfman, 1991), styrofoam balls of various sizes and an orbiter planetarium (Delta Education, 1993).

Every session also included other types of hands-on activity. In some sessions, these activities related to other areas of science that were of particular interest to the children. Charlie liked "making formulas" so the activities with him usually involved chemistry. Jennifer liked plants and animals, so we collected leaves and observed her cat. Whenever possible we used activities related to earth concepts. For example, in one session where the children worked together, we used an activity in which we made boats out of clay and used them with the globe to simulate how the the Greeks figured out the world was round by watching boats arriving and departing (Lauber, 1990).

In their third session, each child was given a journal to record important information at the end of each session. At first, the children only drew in their journals, but gradually with my encouragement they also began to write using invented spelling. Sometimes I suggested what they should record while at other times they chose what they would write and/or draw.

Data Analysis

I collected and analyzed the data simultaneously using the constant comparative method (Glaser & Strauss, 1967). Dillon's (1989) case study provided a model for the methodology, i.e., like Dillon I color coded data according to categories that emerged from the data and constructed maps of the categories. Following Patton's (1990) guidelines for qualitative research, transcriptions, journal entries, field notes, and parent and teacher interview responses were considered in relation to each other in interpreting the data.

To increase the objectivity of the analysis, in June 1992, October 1992 and June 1993, my graduate assistants and I independently answered in writing the questions that were the focus of the study and compared our answers to the questions. Only ideas that met Strike and Posner's (1992) criteria (ideas that represented an organizing role in the child's cognition and generated other incorrect ideas) were categorized as misconceptions. Moreover, an idea was only categorized as a misconception or a scientific idea when the same idea was expressed in different ways on different occasions. We were particularly careful about considering a child to have corrected a misconception because as was found by Vosniadou (1992) , they often expressed misconceptions and correct ideas at the same time. In order for us to consider that the child no longer had a misconception, the child had to express the correct idea and provide evidence of no longer holding the misconception. Our categorizations and interpretations of the data were generally consistent with each other except when, occasionally, one of us included a piece of evidence not mentioned by the other. These differences were resolved by rereading the transcript.

Sources of ideas were identified in two ways. I asked the children and their parents how they learned the ideas they expressed and we looked for agreement between parents' and children's answers. When we inferred sources of ideas from the data we looked for agreement between the two independent interpretations.

Findings and Discussion

The Earth

At the outset of the study, both children said the earth was round. However, in response to the question (Vosniadou, 1987), "If you walked for many days in a straight line, where would you end up?", Charlie and Jennifer both said they didn't know. I then asked Jennifer if there was an edge to the world. She replied that there was and said that she could fall off the edge if she kept walking. Charlie, on the other hand, immediately followed up his "I don't know " in a manner suggesting that despite this answer he understood the earth was a round sphere. His citing of sources in the transcript below was supported by his parents. (In transcript sections quoted in this paper, C will represent Charlie, J, Jennifer and K, myself.)

C: **If** the earth was flat, I would be walking and then I would walk right off the edge.

K: Is the earth flat?

C: No, so I would keep on round and round (making a horizontal circle in the air with his hand). Would I go upside down? No, because here people think the earth is flat , but it isn't.

K: How do you know that?

C: It's on my space book. And then I have a telescope with slots, and it shows you the moon and the earth and the stars. It came with slots, and you put them in. I'll try to find it.

(The telescope referred to is an educational toy that Charlie received the Christmas that he was 4. It has slides containing pictures of the earth and other locations in space.)

In our fourth session, asked to explain why he had drawn the ground flat when he said the earth was round (Vosniadou, 1987), Charlie replied, "Because that's what it looks like from here. But from outer space it looks like this (pointing to the picture of the round earth he had previously drawn). In our seventeenth session, while reading about how medieval sailors believed that there was an edge to the world (Anno, 1979), Charlie at first agreed with this idea but then immediately corrected himself. He never gave any other indication that he viewed the earth as anything but a sphere.

In her third session, Jennifer gave evidence of understanding that the earth was a sphere. When asked to make the earth with clay, she made a round ball. When the same questions used in the first session were repeated, she said that a person who walked in a straight line would end up "back here" (using the clay ball to show me that the person would walk around the earth and would not fall off the edge). She then volunteered, "I know I said before he would, but I thought it was flat. My teacher told me the earth is round."

(Since Jennifer's teacher refused to be interviewed, it was not possible to determine whether this had indeed happened.) In our seventh session in response to a question, Jennifer indicated that the earth looked flat to us because you had to go out into space to see that it was round. She then volunteered that she knew the earth was round before I showed her. When asked how she knew, she replied that she had heard the story of Christopher Columbus in school.

In three sessions in the summer of 1992 (Charlie's ninth, tenth and eleventh sessions, Jennifer's seventh, eighth and ninth sessions), the children engaged in two activities demonstrating how the Greeks learned the earth was round (Lauber, 1990). The first activity using clay ships was described previously. The second activity involved helping the children discover that a round flat disc (a plate) and a cylinder (a can) would make curved shadows in some positions but only a sphere (a ball) would make a curved shadow in every position. Since the shadows of the earth the Greeks saw on the moon were always curved, they concluded the earth must be round. Even months later both children referred to these activities when we discussed the earth. For example, in Jennifer's eleventh session, asked to tell what she knew about the earth, Jennifer replied that the earth is round and in space. She then continued:

J: The Grins, people a long time ago thought it was flat.

K: The Grins? You mean the Greeks? They thought it was what?

J: Flat, but a little curved like a plate. But it's really round like a ball.

K: Uh huh. And how did they find that out?

J: When they saw the ships- when they went down they saw their tops, I mean their bottoms go down first , then the sails.

K: Oh.

J: And then when they were coming back, first they saw the sail, and then they saw the bottom.

In her fourteenth session, she cited How We Learned the Earth is Round (Lauber, 1990) as evidence for the earth being round and told me that she bought it at her school book fair. When asked what part of a ship you would see if the world were flat, she replied,"You would see the whole ship...the whole part." Jennifer's initial responses and her memory and correction of those responses suggest that she came to the study with a view of the earth as a flat disc , but that she advanced to the idea of the earth as a sphere.

Statements in Jennifer's early sessions also suggested that she did not understand that the earth was surrounded by space. In our second session, looking at a picture in the book, <u>Our Planet Earth</u> (Wood, 1992) that depicted the moon below the earth in space, Jennifer gave further evidence for the view of earth as a flat disc with sky only above. She said that the moon was in the wrong place in the picture and should be above the earth so it could shine down. Then she said, "Oh, maybe because the earth spins." and finally, "Maybe the man who drew it held it upside down.". However, a month later as she was doing a puzzle showing all the planets surrounded by space, I asked her what was below the earth. After saying I don't know, she looked at the puzzle and said,"Stars and space". Asked about what surrounded the earth in our fourth and ninth sessions, she responded, "Space", but the puzzle was present in both cases. As noted previously, however, in our eleventh session she volunteered that the earth was in space and the puzzle was not present. In our fifteenth session, she used the idea that the earth was surrounded by space as evidence for another misconception that she came to the study with, i.e. that we live inside the earth. In our first session, Jennifer drew a picture showing herself inside the earth. In our fifth session she rejected information about gravity pulling toward the center of the earth from the book, <u>Gravity is a Mystery</u> (Branley, 1986a) saying, "But we are in the center, so it would be silly." I then questioned her about whether we lived on the outside or the inside of the earth, using a styrofoam ball that I had cut in half at the beginning of the session to demonstrate the inside and outside of the earth. We started talking about what the inside of the earth was like and looked at pictures in <u>Look Inside the Earth</u> (Ingoglia, 1989). This seemed to help her understand that we live on the outside of the earth because she pointed to the outside of the ball and said, "We live in the center out here.". In our fourteenth session, she again said we live on the inside of the earth but then corrected herself in response to my probing:

> K (pointing to the styrofoam ball that had been cut in half in a previous session): Where is the outside and the inside of the earth?
> J (pointing to the correct locations): Outside, inside.

K: That's right.

J: We live on the inside of the earth.

K: Do we live on the inside? What is it like on the inside?

J: I mean on the outside.

K: We live on the outside of the earth.

J: Because if we lived on the inside, then we would be burning our heads off.

In our fifteenth session, in response to a question Jennifer again indicated that we lived inside the earth and added, "If we lived outside the earth, we would say 'Hi, earth!'". I again used the cut styrofoam ball to have her identify the inside and outside of the earth. The following discussion took place as I realized Jennifer was understanding outside of the earth to mean out in space.

J (pointing to the outside of the ball): Oh yeah. We live here.

K: Yeah. We live on the outside of the earth. That's kind of confusing.

J: Cause if you were inside the earth you would get all hot.

K: Right. When I said surrounded by space, I meant out here (pointing to the area around the ball) We don't live out here, but we live on the outside of the earth (pointing to the surface of the ball) because the inside like you said is very hot.

J: But it feels like we're inside the earth.

K: Why does it feel like we're inside the earth?

J: Because we can't see space from here.

K: No. Actually you know why that is? There's something called the atmosphere, the air that surrounds the earth. And we have to go through the atmosphere to get into space.

At the end of this session, Jennifer drew a picture of herself on the outside of the earth. In our seventeenth and last session, when I reminded her of our conversation in the earlier session, she said that we lived on the outside of the earth, but we couldn't see space. I also read her what she said in the fifteenth session about feeling like she lived inside the earth and told her other people felt that way also. I then read her a section from Anno's Medieval World (Anno, 1979) describing the medieval notion of transparent celestial spheres. As I read it I realized it was too difficult because I wasn't understanding it myself. When the book described the celestial spheres as like the layers of an onion, I got an onion to show what was meant. Jennifer was interested in the fact that onions make you cry rather than in their connection to celestial spheres.

Jennifer did not seem to know anything about gravity at the outset of the study. In our fourth session, I showed her the inflatable globe with a figure stuck to Australia. When I asked her why the people in Australia did not fall off the earth, she replied that there was something sticky on the earth that kept us from falling off. At the beginning of our fifth session, when I asked her what was keeping her on the earth, she replied, "Gravity". When I asked her what gravity was, she replied, "Gravity is something you don't see, but it keeps you on the ground. My teacher talked about it one day."

Also in the fourth session, her confident choice out of four pictures of the one showing a ball dropping through a hole into space (Nussbaum, 1979) was evidence that she had a misconception that there is an absolute up and down in space. She was generally consistent in giving responses indicating the presence of this misconception. In the same session, shown a picture of a figure on top of the earth and asked to draw the path of a ball dropped by the figure (Nussbaum & Novak, 1976), she drew a line outside and around the picture of the earth with an arrow pointing to the bottom of the picture. In the fifth session, as soon as I finished reading the section in Gravity is a Mystery that told what would happen to a person if he/she fell through a hole in the earth, Jennifer commented, "Maybe it isn't right. Maybe it's a fairy tale." As described previously, she used her idea that we lived inside the earth as an argument against gravity pulling toward the center of the earth. Then temporarily convinced that we live outside the earth, she used this information as evidence that Gravity is a Mystery had to be a fairy tale because if a person fell through a hole in the earth he would get burnt. Finally, besting me in the discussion that followed, she showed that she could think like a scientist.

> I: Well, they didn't say he did (fall through a hole in the earth). They said, "Suppose you could dig a hole." They didn't say somebody really went to the center of the earth. They said if you jumped into the hole

you would fall down. They did not say someone jumped down. They are telling you what they think would happen if you did that.

J: They think. They think.

K: Right.

J: So they don't know.

In our sixth session, Jennifer again chose a picture showing a ball falling to the "ottom of space". Shown Gravity is a Mystery she remembered that it said gravity would pull you toward the center of the earth, but said she did not believe that. Shown other pictures used by Nussbaum (1971) and Mayer (1987) showing the hole in the earth as horizontal and diagonal, she drew the path of the ball falling to the bottom of the picture. In our fourteenth session, when asked to show what would happen to a ball dropped by figures stuck to various locations on the inflatable globe and a styrofoam ball with a hole through it, she consistently showed the ball "falling down into space". In her journal, she drew a picture of a ball falling through a hole in the earth. There was one inconsistency in her early responses. In our fourth session, asked to draw what water would look like in glasses depicted as upside down near the South Pole (Nussbaum & Novak, 1976), she did not show water falling out of the glasses. In our sixteenth session, there were signs of changes in her ideas about gravity. I used the inflatable globe and a figure stuck to Antarctica to support a discussion regarding what would happen to a ball dropped through a hole in the earth.

K: What would happen if there was a hole in the earth and this person dropped a ball through it?

J: People might think that if you dropped a rock into the hole it might go back out.

K: Why would they think that?

J: Because it's at the bottom of the earth.

K: Uh huh.

J: They think that maybe the gravity did that.

K: But what does gravity pull you toward?

J: Down.

K (sticking the figure on the top of the inflatable globe): If you're standing here, where is down?

Jennifer points her finger in a downward direction. I move the figure to the South Pole.

K: But suppose this was you. If you were here, where is down?

Jennifer points to a spot in the middle of the globe.

K: Yeah, so it's pulling toward the ?

J: Middle

K: Right. So where would the rock end up then?

J: In the middle.

After a brief discussion in which I demonstrated to Jennifer that where ever the figure is on the globe, down will always be toward the center of the earth, she asked, "Do you still have that book?". Understanding her to mean <u>Gravity is a Mystery</u>, I took out the book and we reread it. In her journal, Jennifer drew a picture of herself dropping a ball through a hole to the center of the earth. She also wrote, "Gravity pulles you down to the ceter of the earth.".

In our seventeenth and final session, in addition to the section on celestial spheres, I read the following section from <u>Anno's Medieval World</u>:

> It's the earth that moves wrote an astronomer, and furthermore, the earth is round. Well, that is what the sailors had said, but if it were true, people reasoned, then surely everything on the other side would be upside down, and if it were true that the round world turned, then surely everything, people and houses, bees and trees, would fall off into empty air.

In the discussion that followed, Jennifer volunteered that gravity pulls you toward the ground not the air. Despite her resistance to earlier attempts to correct her misconceptions about the earth, it appears that during the study Jennifer advanced from Nussbaum's (1979) Notion 1 view of the earth as a flat disc to a Notion 5 view of the earth as a sphere surrounded by space with people living on the outside of the earth and gravity pulling towards its center.

At the outset of the study, Charlie seemed to have a Notion 3 view of the earth as surrounded by space with people living on the outside of the earth. He was consistent in several sessions in describing the earth as surrounded by "sky" or "space". In his fourth session, he drew a picture of himself on the outside of the earth.

The following discussion which took place in our first session suggests that Charlie came to the study with some understanding of gravity. He was building a tower with blocks, and it fell.

K: Why did that fall? (I was referring to the fact that he had placed the last block on carelessly and crookedly.)

C: It's because of gravity.

K: Really! What's gravity?

C: It's a force that pulls things down.

K: Who told you that? How do you know about gravity? Who told you about gravity?

C: Watched it in a movie.

In our fourth session, Charlie appeared to generate the same misconception as Jennifer, i.e. that gravity pulls to the "bottom of space". (This misconception is consistent with Nussbaum's (1979) Notion 3 view of the earth.) Shown the same four pictures (Nussbaum, 1979), he too chose the picture that showed the ball dropping through the hole to the bottom of the picture. However, unlike Jennifer he showed doubt and confusion about his choice (See the transcript below).

K: I'm going to show you some pictures. We're going to pretend that this is - these pictures are pictures of the world, and the world has a hole through it. Okay, I want you to look at these pictures. Suppose the world had a hole through it, and this is you (pointing to the figure stuck on the inflatable globe). You're standing and you have a ball in your hand. There are four pictures I want you to look at. Now you see - this is supposed to be the world (pointing to the pictures on separate cards). Just like the globe. And if the world had a hole through it, and you were standing at the hole, and you dropped something, would it go here and stop (pointing to a picture showing the ball stopping at the bottom of the earth)?

C: No.

K: Would it go here and stop (pointing to the picture of the ball stopping in the center of the earth)?

C. It would go here and stop (pointing to the picture of the ball falling through the hole to space at the bottom of the card).
K: It would go there and stop. And what is this here (pointing to the space at the bottom of the card)?
C: The bottom of the ...space.
K: That's space. So if you dropped it, and there was a hole it would go all the way through the earth...
C: Maybe I'm wrong...where the dinosaurs are...never see it again. It would get turned into a fossil like everything else and ...
K (pointing to the space at the bottom of the card): So you think down here, that's where the dinosaurs are.
C (pointing to the same place): Well, for real, it's waaay down in here, in Australia.
K (pointing to the same place): But see, is this inside the earth?
C: This is inside the earth.
K: Oh it is. (pointing to the picture of the earth) But look, wouldn't this be inside the earth in here?
C: No (pointing to the space at the bottom of the card) This is the bottom of the earth like... I don't know. I don't know what I'm even talking about. Sometimes I start doing things I don't even...
K: Well, before you said it was space, and then you said it was the inside of the earth.
C: It's the inside of the earth (pointing to the picture of the earth) This is the beginning of the inside of the earth and then...
K (pointing to the picture of the earth) : But look, here's the earth ... so show me where the inside of the earth would be.
C (pointing to the space at the bottom of the card): It would be right here...the bottom of the earth.
K (pointing to the same place): Is it inside the earth, if it falls down here?
C: Yes. Be the bottom of the, the bottom of space. I was right the first time.

His doubt and confusion suggest how difficult this task was for Charlie. They also suggested to us that this task helped Charlie to construct a misconception that is an attempt to synthesize intuitive and scientific ideas.

He had never shown any problem with understanding the concepts of outside and inside even in relation to the earth. He also understood that gravity was a force holding people to the earth. However, in presenting him with two dimensional pictures even with the support of the three dimensional globe, I was giving him a task that is an abstract imaginary one. He had to try to imagine the earth as three dimensional and realize that the picture is a picture of one side of the outside of the earth. The card containing the picture has an absolute up and down, but in order to answer the question correctly, he would have to ignore this in dealing with a situation that is hypothetical, i.e., we cannot dig a hole through the earth. It is not surprising to hear Charlie say "I don't know what I'm even talking about.". It was also not surprising that he was not content with that response. His parents and teachers as well as I have noticed that Charlie doesn't like to say "I don't know." And so it seems he resolved his confusion by relying on the perceptually salient absolute up and down, ignoring his information about dinosaur fossils inside the earth resulting in the logically inconsistent idea that the bottom of space is the inside of the earth.

Once he had made his decision, like Jennifer Charlie was consistent in his responses to related questions. Later on in the same session, using a figure stuck to the bottom of the inflatable globe, I asked him what would happen to a ball dropped by the figure. He responded that it would float into space, and there was no gravity in space. However, when I asked him if there was gravity on earth, he said there was.

K: And the gravity pulls you all the way down to where?

C: The floor.

K: What if there was a hole in the earth? What would happen?

C: And you were heading right for it?

K: And you went down the hole. Where would you end up?

C: You would end up in space and never see your mommy again.

In our fifth session, given the same picture as Jennifer of a figure on top of the earth (Nussbaum & Novak, 1976), Charlie drew the ball falling around the outside of the earth though not to the bottom of the card. Unlike Jennifer, he showed water falling out of glasses depicted upside down at the bottom of the earth. Using the styrofoam ball with the hole in it, he also said a ball dropped through the hole would fall to the "bottom of space".

In Charlie's sixth session, after my reading of Gravity is a Mystery described previously in relation to Jennifer, he immediately responded that gravity pulled toward the center of the earth. At my direction, he also drew a picture showing that a ball dropped through a hole in the earth would stop at the center. This rote learning was not remembered, however, for in our seventh session he again chose from the four pictures the one showing the ball falling to the "bottom of space". This time I used the inflatable globe with a figure stuck to the southern part of South America. I told him I had just come back from South America, and I did not fall off the earth. We turned the globe to show him that for the people in South America, it was just like it was for us. They thought they were on the top, and we were on the bottom. We then reread the relevant section of Gravity is a Mystery. The next time gravity was discussed was in our twelfth session. At this time, there were signs of changes in his ideas. I asked him to tell me what he knew about the earth, and we made a semantic map of his ideas. I added Antarctica to his list of continents and showed him where it was on the inflatable globe.

C: Oh, they don't fall off here though.
K: Why not? Why don't they fall off?
C: Gravity.

Later on in the same discussion, we talked about the inside of the earth. Charlie told me it was hot, and you couldn't dig a hole through it. Then the following interchange took place:

K: Remember that book we read, and it talked about if you did dig a hole through it what would happen.
C: You'd go up and down and up and down.
K: And if you dropped a ball? What would happen to the ball?
C: It would go voo to space.
K: It would fall right down to space?
C: Yup, cause it's gravity. No, it would go to the middle. It would go to the middle.
K: Oh.
C: No, it would go up and down, up and down until it would slow down and go into the middle.

K: Oh, so first you thought it would go in space. What made you change your mind?
C: Cause gravity tries to put things in the middle.

In the same session, Charlie also came up with a very unscientific idea about gravity, namely that first there was gravity in only one place on earth and then the wind blew it around the world. Asked where he had learned this idea, he said he just thought that. However, in our eighteenth session, six months later, he described gravity as a force like the pull of a magnet (We had played with magnets in an earlier session.). I then used the inflatable globe with a figure stuck to Antarctica.

K: He went to the South Pole, and he's standing there. How come he doesn't fall off?
C: Because gravity wants to pull you to like where the, like this (points to the center of the globe) but like the middle and deeper.
K: Outside or inside?
C: Inside.
K: So does gravity pull to the bottom of space?
C: No.

I then showed him a picture of a man standing next to a hole through the earth and asked him to show me where the ball would go if the man dropped it (Nussbaum & Novak, 1976). He pointed to the middle of the hole. When I asked him why it wouldn't fall out the hole, he said, "Because gravity pulls toward the center.". Charlie's ideas were more sophisticated than Jennifer's at the outset of the study, but his ideas also advanced so that at the present time he also appears to have a Notion 5 view of the earth.

Day and Night

In addition to the earth concepts discussed in the previous section, two major counter-intuitive ideas need to be acquired in order for children to understand the scientific explanation for day and night:

1. The earth moves rather than the sun.

2. The rotation or spinning of the earth not its movement around the sun causes day and night.

Another related idea is the recognition that it is a different time on different parts of the earth. Charlie came to the study with this idea. His aunt recounted that when he was four, he told her that it was a different time in Ireland than it was here. (When he was three, Charlie spent two weeks in Ireland with his family.) His father also mentioned that Charlie often asks questions like "Are the people in China eating dinner while we're eating breakfast?" In our fourth and sixteenth sessions in answer to questions, Charlie indicated that when it was day here it was night on the other side of the world. In our eleventh session in teaching Jennifer about day and night I asked her whether it was the same time for her grandfather in California as it was for us. She said it was because California was part of the United States. She also said she knew it was a different time in Hong Kong because when her daddy went there he called her and told her it was different.

Although Charlie did not clearly express the misconception that day and night are caused by the movement of the sun, initially he did show confusion over whether the earth or the sun moves. In our first session, when I asked him what he knew about day and night, he said, pointing to different parts of the sky, "The sun goes from here to there."

K: So the sun moves around?

C: It stays in one big circle like this (making a circle with his hands), so this side would have light, this side would have light.

K: Are we talking about the sun or the earth?

C: The earth.

Two weeks later during a discussion with Jennifer, his aunt and myself at at restaurant, he said that the sun went around the earth. His aunt immediately corrected him. In our twelfth session, he interrupted my reading of <u>The Way to Start a Day</u> (Baylor, 1977).

C: The sun gives heat and sometimes it goes around. I think the sun stays still or something.

K: The sun stays still?

C: I think so.

Asked to tell what causes day and night in our sixteenth session, Charlie volunteered, "And the sun doesn't move, the earth does.".

Jennifer came to the study with the idea that it was the earth that moved not the sun. In our fourth and sixth sessions she expressed that idea in response to questions. However, in the discussion with Charlie at the restaurant, she said she used to think the earth went around the sun, but her daddy told her the moon went around the earth, and then she realized that the earth went around the sun. The following exchange from the sixth session and many of her statements in later sessions suggest that she had the misconception that the movement of the earth around the sun causes day and night.

K: Does the earth move or does the sun move?

J: The earth.

K: How do you know that?

J: Because I'm learning it at school.

K: Who told you that?

J: The teacher. She told us about around, and when it gets to the other side of the sun it's night time.

In our ninth session, when Jennifer said that the earth goes around the sun in 24 hours, I corrected her. I then taught both children about the two movements that the earth makes by playing the part of the sun and having them dance around me. Yet in the eleventh session, when I asked her to dance the part of the earth, she danced around me without spinning. When I asked her if the earth moved any other way, she said,"No." At the end of the session, she wrote in her journal, "The earth goes around the sun.". In the twelfth session, she danced both movements, and we talked about the earth revolving on an imaginary axis as the cause of day and night. Jennifer then read <u>Day and Night</u> (Nelson, 1990) which explained how the earth's spinning causes day and night. In her journal, she wrote,"The earth spins rond and rond the sun.". After reminding her of the two movements of the earth, I added "and goes" after "spins". In the thirteenth session, when we used different sized styrofoam balls to model the movements of the earth, she modeled both movements. Then she read <u>The Sun is Always Shining Somewhere</u> (Fowler, 1991) and <u>What Makes Day and Night</u> (Branley, 1986b), looking for new information. She indicated she already knew the spinning of the earth causes day and night, but she may have been using spinning the way she used it in her journal. In our fourteenth session, when I asked her which movement of the earth caused day and night, she replied, "Both". In our fifteenth session, although she again danced both movements of the earth and talked about the earth spinning, it was not clear that she understood spinning as different from the earth's movement around the sun. While she now uses more scientific terms about day and night, I am not confident that she has a scientific view of the cause of day and night.

In his eighth session, after being introduced to the two movements of the earth in his previous session, Charlie volunteered that the earth spins and danced both movements for me. When I asked him how he knew about the cause of day and night, he said he had learned it from the same TV show he talked about before (My son told me that this show was a PBS show called "The Astronauts' View of the Earth".). In the thirteenth session, I used a light and the inflatable globe to demonstrate how the spinning of the earth causes day and night. Nevertheless, in the fourteenth session, when we came to a striking picture of the sun and the earth, showing half of the earth in light and half in darkness in The Earth and Sky (Jeunesse & Verdet, 1989), he said the earth would have to go around to the other side of the sun for it to be daylight on the other side. When I asked him how the earth moved, he corrected himself, saying, "Oh yeah. It's like a spinning top. That's how we get day and night." In our fifteenth session, we read the two books Jennifer read in her thirteenth session. However, later in the session he used the styrofoam balls to demonstrate that the movement of the earth around the sun causes day and night. I then did another demonstration with the light and the inflatable globe. In his sixteenth session, asked what caused day and night, he spun the globe; in the seventeenth session he said, "It rotates" and in the eighteenth session, "The part that spins like a top". It appears that Charlie now understands that it is the rotation of the earth that causes day and night.

The Seasons

My work with middle grade children had suggested to me that in order to understand the cause of the seasons, children have to understand not only that the earth is tilted and that it is this tilt that causes more direct sun rays and longer days in the summer, but also that we speak of the earth as having two hemispheres (Northern and Southern) and that these hemispheres have opposite seasons. Children who understood this last idea seemed to understand that this idea was inconsistent with the idea that summer is warmer because the earth is closer to the sun.

Neither Charlie nor Jennifer had knowledge about the hemispheres at the outset of the study. However, in response to their questions about the line on the inflatable globe, I taught them about the equator and the Northern and Southern Hemispheres. Although both children can explain that hemisphere means half a sphere and a sphere is a ball, my use of placemats that depicted the Eastern and Western Hemispheres as well as the Northern and Southern Hemispheres confused them. The children love the place mats, and use them when they come to visit for a meal. However, Charlie noticed that their depictions of the globe were not correct, and in our last session, Jennifer said that there are four hemispheres.

Both children came to the study understanding that there are four seasons with different weather. They could name the seasons in correct sequence and describe many things that happen in nature at different seasons. Neither child ever gave any indication of having the misconception that the seasons are caused by the distance of the sun from the earth. When asked initially why it was warm in summer and cold in winter, both children gave non -scientific explanations. Charlie responded, "Cause it can't be too hot, it can't be too cold".

When I again asked Charlie why this was so, he replied, "The clouds."

K: How do the clouds change the seasons?

C: The clouds make winter, and they help make spring.

K: And how do the clouds do that?

C: Cause they rain and in winter ...

K: But let me ask you a question. When it's summer there are clouds, right?

C: Yeah but...

K: And they make rain. And in the winter they make snow because it's so cold. Why is it cold in the winter and warm in the summer?

C: That's one I don't know.

Although I told Charlie we would be learning what caused the seasons the next time, once again he did not like not knowing. A week later, on the way to school he asked his father what caused the seasons, and his father told him abut the tilt of the earth. At the beginning of the next session, he said to me, "I figured out why it's warm in summer.". Then he explained about the tilt of the earth, using his body to show me what tilt means. He did not tell me he had learned about the tilt from his father. His father mentioned it to me several days later.

Our last session in May 1993 was the first time I asked Jennifer about the cause of the seasons. She replied that it was warm in summer "because they wanted summer to be a hot season." When I said she then really didn't know why, she agreed. Then we looked at the calendar. With Jennifer's help, I had been recording the time of sunrise and sunset since the end of January. When we looked at the calendar in late February, Jennifer noticed the pattern of the days getting longer. She now noticed that the pattern had continued.

> K: Okay. I said to you, "Why is it hotter in summer and colder in winter? You can tell me a little bit now, one reason why it's warmer in summer.
>
> J: Because the sun, more hours of sunlight.

Charlie too had noticed the pattern of the days getting longer when I showed him what I was recording on the calendar. Both children had also noticed that the globe was tilted. In our fifteenth session, when we were constructing a semantic map of <u>earth</u>, Jennifer volunteered that the earth was on a slant. In March, I also read both children an article (Time, March 8, 1993) stating that the pull of the moon's gravity caused the earth to tilt in one direction. We played games in which I was the moon, and they were the earth, and I caused them to tilt. At the beginning of May, when I obtained the orbiter planetarium, the children were given it to play with during a family gathering. They asked how it worked, and the family figured it out together. With the help of my questions, the children noticed that the part where we lived (the Northern Hemisphere) was tilted toward the sun during our summer months and away from the sun during our winter months. I mentioned this to Jennifer in our last session. She wrote in her journal:

How the Earth Tills

In the summer the earth tills to the sun. In winter the earth is tilled away from the sun.

I pointed out to her why it should say "northern hemisphere" instead of earth, and we corrected the journal together.

After playing with the orbiter planetarium once again in our last session, Charlie drew a picture of it in his journal, labeling the earth, the sun and the "seesons". He then wrote, "I just did an ecspeirament that is about the seesons." He was getting "tired of writing" so he dictated the rest of his journal entry to me. "The earth tilts and that's how they make the seasons. The moon pulls the earth. The part of the earth tilted toward the sun is hot. The part of the earth tilted away from the sun is cold." Charlie and I also talked about the whether direct or slanted sun rays would be hotter. Charlie hypothesized that direct rays would be hotter. We then did an experiment in which we put two thermometers in the sun slanting one so that it got the direct rays of the sun. The fact that the slanted thermometer got the direct rays and thus was hotter was too difficult for Charlie to understand, so that after the experiment he decided that slanted rays are hotter. Our next step will be to find a way to correct this erroneous idea. However, for the most part, the children are well on their way to understanding the cause of the seasons.

Summary and Conclusions

Charlie came to the study with a number of scientific ideas about the earth:

1. The earth is a sphere.
2. We live on the outside of the earth.
3. Gravity is a force that pulls things down.
4. It is a different time at different places on the earth.
5. There are four seasons: winter, spring, summer and fall. These seasons have different weather, and the behavior of plants, animals and people is affected by the seasons.

As can be seen from sections of transcripts quoted earlier, Charlie consistently referred to TV as a source of his scientific ideas. He also mentioned books, toys and museums on more than one occasion. It is important to note that Charlie asks questions about all his experiences, and his parents and other members of the family encourage his questions although at times he overwhelms them. Asked where he thought Charlie got ideas about science, his father replied:

> Well, where ever we go - like when we go to museums or whatever, we don't just go and have a walk. We explain it all to him. So I think he gets it from his parents, and also we learn together because I don't know everything in the museum. I explain it to him. And TV shows. We watch a lot of TV shows together. Mr. Wizard is a very big thing. We still watch that together.

Although he did mention the QUEST progrma on one occasion, Charlie never mentioned his regular school program as a source of his ideas. Before entering kindergarten, he asked his father if he would be learning science. At the end of his kindergarten year, when asked what he had learned about science in school, Charlie replied, "You don't learn science in school. You learn it outside of school." His kindergarten teacher and the research of Linn and Meyer (1991) support his idea that there is very little science instruction in the primary grades.

Jennifer also came to the study with some correct scientific ideas. She had the same ideas about the seasons that Charlie did and also understood that it is the movement of the earth rather than the movement of the sun that causes day and night. Although she too mentioned books and museums on several occasions, unlike Charlie, she consistently referred to school as the source of her ideas In first grade, she had a science workbook (Silver Burdett & Ginn, 1987) which she said was the only way she learned science. In second grade, there was no workbook and according to her mother no science instruction. On two occasions, Jennifer also mentioned learning ideas from her father. Over the course of the study, Jennifer's parents began to encourage her to engage in more scientific activities. Her mother enrolled her in several science courses in addition to the QUEST program, and she and her father built a model of the solar system for the school science fair.

At the outset of the study, Jennifer did not ask questions. In fact, unlike Charlie, after giving her response to a question, she would usually ask if she was right. I discouraged this, encouraging her to have confidence in her own ideas. Her reaction to the book, Gravity is a Mystery, described earlier, is evidence of the coonfidence that she developed in working with me. However, she never questioned information attributed to her teacher. Although there is a temptation to attribute this behavior to Jennifer's gender, more research needs to be done to determine whether it is typical of young girls.

It was unclear whether Charlie came to the study understanding that the earth was surrounded by space and that it is the movement of the earth rather than the movement of the sun that causes day and night. Over the course of the study, he gave evidence of constructing two misconceptions, i.e., that gravity pulls to the "bottom of space" and that day and night is caused by the movement of the earth around the sun. Jennifer apparently came to the study with the same misconception about day and night as Charlie. In addition, she believed that the earth was a flat disc with a sky above and that we live inside the earth. She too constructed the same misconception about Charlie once she was exposed to information about gravity. It has been suggested that young children construct misconception because they attend to perceptually salient but irrelevant information (Gardner, 1991). It appears that the pencil and paper tasks designed to discover whether Charlie and Jennifer had a misconception about gravity may have contributed to the construction of this misconception by presenting them with a situation in which incorrect information was perceptually salient (the card on which the picture of the earth is presented has an absolute up and down). One implication of this is that teachers and researchers should carefully consider how they design tasks to assess the presence of misconceptions to be sure that they are not helping to create a misconception.

The children's ability to accept mutually contradictory ideas and their different understandings of the language used in instruction helped them to maintain their misconceptions. However, despite the many mistakes that I made, there is evidence that Charlie and Jennifer corrected some of their misconceptions and expanded their scientific understandings as a result of instruction. Both children now understand that the earth is a round sphere surrounded by space, that we live on the outside of the earth and that gravity pulls toward the center of the earth. They know that the tilt of the earth and its movement around the sun are responsible for the longer days that are part of the reason for the seasons. Charlie but perhaps not Jennifer also understands that the rotation of the earth causes day and night.

There were a number of aspects of the instruction used in the study that appeared to be helpful to the children and that can be applied to instruction in the classroom. First, the fact that I was the children's grandmother created a climate of trust in which the children felt comfortable asking questions and challenging ideas. Reardon (1993) provides many ideas for creating this kind of climate in the classroom.

Second, ideas were presented to the children in small doses and based on Gardner's (1983) suggestions the same ideas were returned to in ways related to linguistic, logico-mathematical, spatial interpersonal and bodily intelligences (listening to and reading stories, drawing pictures, playing with models and clay, doing puzzles, dancing etc.). Thus in accord with the recommendations of many science educators and cognitive scientists (e.g., Bruer, 1993; Minstrell, 1989), the children were given sufficient time to reflect on the implications of what they were learning. As Jennifer remarked to me, "You're a grandmother. There's time. It's not like school."

Third, in accord with the prevailing view of science instruction, hands-on activities were used as much as possible given my lack of knowledge in the area of science education and the nature of the concepts being taught. In working with the children, I discovered that it was important to make these ideas that they could not directly experience personally meaningful. Telling the children that I had been to South America and didn't fall off the earth, reminding Jessica about her father going to Hong Kong, pretending that the figures stuck to the globe were the children, helped them to learn the ideas and see their relevance as we worked with the models. I also discovered that hands-on activities are not always the best way to teach a concept. In order for a hands-on activitiy to be helpful, it must be developmentally appropriate and the child must have the previous understandings assumed by the activity. Charlie loved making holders for the thermometers and putting them out in the sun to see whether direct or slanted rays would be hotter. However, for a child his age the idea that the slanted thermometer got the direct rays was just too complicated particularly since we had not done any work with shadows. It seems to me that in this case, simply confirming Charlie's hypothesis that direct rays are hotter would have been a better idea.

Fourth, I tried to strike a balance between direct teaching and inquiry. Looking back over the study, I realize that in the beginning I overrelied on providing information to the children both orally and through trade books. As the study progressed, I relied more and more on benchmark lessons (Minstrell, 1989) in which the manipulation of models and my questions and explanations were combined to help the children see the inconsistency in their misconceptions and provide support for scientific ideas. For example, helping the children to understand that for people in the southern hemisphere, we are upside down, helped them to learn that gravity pulls to the center of the earth. In the end, I came to rely more on guided inquiry. This required time, time to record sunrise and sunset over a period of months, time for the children to play with the orbiter planetarium. The children's emerging understanding of the cause of the seasons suggest that it was time well spent.

Fifth, I found that books did have a valuable role to play in science instruction. The children learned from them and cited them as sources of their ideas. However, non fiction trade books could not just be read aloud like stories because even the simplest of them usually contained too many ideas to be taken in at one time. They had to be read in small sections to provide information about a particular idea, and reread to clarify confusing ideas. Setting purposes and providing prereading and after reading activities was helpful, but demonstrations often needed to be part of these activities. Ideas in the books needed to be carefully considered in order to ensure that they were not being presented prematurely. Using myths and tradebooks that presented science as a story helped the children to expand their ideas. It also helped them to see that there intuitive ideas were not dumb and that scientists' ideas change too. Further collaborative research by science and reading educators should be conducted to determine whether this approach to science instruction helps children to see that science is "an extension of common sense not an esoteric alternative to it" (Lemke, 1990).

Sixth, writing and drawing in their journals allowed the children to engage in the scientific process of recording data. Journals were used to assist their memory and demonstrate to the children how their ideas had changed. Although there is research suggesting the value of writing in middle grade science instruction (Roth & Rosaen, 1990; Santa & Havens, 1991), more collaborative research needs to be done on using writing and drawing in science instruction with young children.

Finally, in my lack of science knowledge, I was similar to the primary teachers described by Mant and Summers (1992). Because of this lack of knowledge I made many mistakes. However, it did have one advantage. As my son said, I was learning science with the chidren. I got as excited as Charlie when our baking soda rocket actually worked, and it worked because we read the directions carefully. My excitement is what Charlie talks about whenever he tells anybody about "doing science with Grandma" If teachers can overcome their fear and become caught up in the excitement of learning science, and if science education researchers and researchers in the areas of oral and written language can collaborate to offer teachers more knowledge about science and how to teach it, science instruction for young children may hold the answer to the prevention of misconceptions resistant to the process of conceptual change.

References

Anno, M. (1979). Anno's medieval world. New York: Philomel Books.

Branley, F.M. (1986a). Gravity is a mystery. New York: Thomas Y. Crowell.

Branley, F.M. (1986b). What makes day and night. New York: Thomas Y. Crowell.

Brewer, W.F., Hendrich, D.J., & Vosniadou, S. (1988). A cross-cultural study of children's development of cosmological models: Samoan and American data. Unpublished manuscript.

Bruer, J.T. (1993). The mind's journey from novice to expert. American Educator, 17, 6-46.

Delta Education, (1993). Orbiter planetarium.

Dillon, D.R. (1989). Showing them that I want them to learn and that I care about who they are: A microethnography of the social organization of a secondary low-track English-Reading classroom. American Educational Research Journal, 26, 227-259.

Duschl, R.A., Hamilton, R.J., & Grandy, R.E. (1992). Psychology and epistomology: Match or mismatch when applied to science education? In R.A. Duschl & R.J. Hamilton (Eds.) Philosophy of science, cognitive psychology, and educational theory and practice (pp.19-47). Albany: State University of New York Press.

Fowler, A. (1991). The sun is always shining somewhere. Chicago: Children's Press.

Gardner, H. (1983). Frames of mind. New York: Basic Books.

Gardner, H. (1991). The unschooled mind. New York: Basic Books.

Gega, P.C. (1986). Science in elementary education. Fifth Edition. New York: Macmillan.

Glaser, B.G., & Strauss, A.L. (1967). The discovery of grounded theory: Strategies for qualitative research. New York: Adline Press.

Goldschmid, M.L., & Bentler, P.M. (1968). Concept assessment kit - Conservation. San Diego, CA: Educational and Industrial Testing Service.

Gordon, C. (1992a). A case study of conceptual change. In C.K. Kinzer & D.J. Leu (Eds.) Literacy research, theory, and practice: Views from many perspectives. Forty-first Yearbook of the National Reading Conference (pp. 161-168). Chicago: National Reading Conference.

Gordon, C. (1992b, December). A case study of conceptual change: A follow-up. Paper presented at the annual meeting of the National Reading Conference, San Antonio, TX.

Guzzetti, B.J., Snyder, T.E., Glass, G.V., & Gamas, W.S. (1993). Promoting conceptual change in science: A comparative meta-analysis of instructional interventions from reading education and science education. Reading Research Quarterly, 28, 117-159.

Hazan, R.M., & Trefil, J. (January 13, 1991). Quick! What's a quark? New York Times Magazine.

Ingoglia, G. (1991). Look inside the earth. New York: Grosset & Dunlap.

Jeunesse, G., & Verdet, J.P. (1989). The Earth and Sky. New York: Scholastic.

Kaufman, A.S., & Kaufman, N.L. (1990). Kaufman Brief Intelligence Test. Circle Pines, MI: American Guidance Service.

Kitamura, S. (1989). UFO diary. New York: Farrar, Straus & Giroux.

Klein, C.A. (1982). Children's concepts of the earth and the sun. Science Education, 65, 95-107.

Lauber, P. (1990). How we learned the earth is round. New York: Harper Collins.

Lemke, J.L. (1990). Talking science: Language, learning and values. Norwood, NJ: Ablex Publishing Company.

Linn, R.L., & Meyer, L.A. (1991). How American teachers teach science in kindergarten and first grade. (Tech. Rep. No. 544). Champaign, IL: Center for the Study of Reading.

Mant, J., & Summers, M. (1992). Some primary school teachers' understanding of the Earth's place in the universe. (Working Paper No. 16) Oxford: Primary School Teachers and Science Project.

Maria, K. (1988, December). Helping fifth graders learn with science text. Paper presented at the annual meeting of the National Reading Conference, Tucson, AZ.

Maria, K., & Hathaway, K. (1991, December). Conceptual change through reading: The effect of instructional support, Paper presented at the annual meeting of the National Reading Conference, Palm Springs, CA.

Maria, K., & Johnson, J. (1990). Correcting misconceptions: Effect of type of text. In S.J. McCormick & J. Zutell (Eds.) Literacy theory and research: Analyses from multiple paradigms. Thirty-eighth Yearbook of the National Reading Conference (pp329-339). Chicago: National Reading Conference.

Maria, K., & MacGinitie, W.H. (1987). Learning from texts that refute the reader's prior knowledge. Reading Research and Instruction, 26, 222-238.

Martin, K., & Miller, E. (1988). Storytelling and science. Language Arts, 65, 255-259.

Mayer, M. (1987). Common sense knowledge versus scientific knowledge: The case of pressure, weight and gravity. In J.Novak (Ed.) Proceedings of the second international seminar on misconceptions in science and mathematics. (pp.299-310). Ithaca, NY: Cornell University.

McGraw-Hill (1989). Comprehensive Test of Basic Skills.

Minstrell, J. (1989). Teaching science for understanding. In L.B. Resnick & L.E. Klopfer (Eds.) Toward the thinking curriculum. Alexandria, VA: Association for Supervision and Curriculum Development.

Nelson, J. (1990). Day and night. Cleveland: Modern Curriculum Press.

Novak, J.D. (1972). The use of audio-tutorial methods in elementary school instruction. In S.N. Postlethwait, J.D. Novak, & H. Murray (Eds.) The audio-tutorial approach to learning. (pp 110-130). Minneapolis, MN: Burgess.

Novak, J.D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. American Educational Research Journal,, 28, 117-153.

Nussbaum, J. (1971). An approach to teaching and assessment: The earth concept at the second grade level. Unpublished doctoral dissertation, Cornell University, Ithaca, NY.

Nussbaum, J. (1979). Children's conceptions of the earth as a cosmic body: A cross age study. Science Education, 63, 83-93.

Nussbaum, J., & Novak, J.D. (1976). An assessment of children's concepts of the earth utilizing structured interviews. Science Education, 60, 535-550.

Nussbaum, J., & Sharoni-Dagan, N. (1983). Changes in second grade children's preconceptions about the earth as a cosmic body resulting from a short series of audio-tutorial lessons. Science Education, 67, 99-114.

Ogle, D.M. (1986). K-W-L: A teaching model that develops active reading of expository text. The Reading Teacher, 39, 564-570.

Patton, M.Q. (1990). Qualitative evaluation and research methods. Second Edition. Newbury Park, CA: Sage Publications.

Reardon, J. (1993). Developing a community of scientists. In Science workshop: A whole language approach (pp.19-38). Portsmouth, NH: Heinemann.

Roth, K.J., & Rosaen, C.L. (1990, April). Writing activities in a conceptual change science learning community: Two perspectives. Paper presented at the annual meeting of the National Association for Research in Science Teachers, Lake Geneva, IL.

Rutherford, F.J. (1991). Vital connections: Children, science and books. In W. Saul & S.A. Jagusch (Eds.) Vital connections: Children, science and books. (pp.21-30). Portsmouth, NH: Heinemann

Santa, C.M., & Havens, L.T. (1991). Learning through writing. In C.M. Santa & D.E. Alvermann (Eds.) Science learning: Processes and applications (pp.122-133). Newark, DE: International Reading Association.

Schollum, B., & Osborne, R. (1985). Relating the new to the familiar. In R. Osborne & P. Freyberg (Eds.) Learning in science: The implications of children's science (pp. 51-65). Portsmouth, NH: Heinemann.

Shayer, M., & Adey, P. (1981). Toward a science of science teaching: Cognitive development and curriculum demand. London: Heinemann.

Silver Burdett & Ginn (1987). Science workbook - Grade 1, Lexington, MA.

Sneider, C., & Pulos, S. (1983). Children's cosmographies: Understanding the earth's shape and gravity. Science Education, 67, 205-221.

Strike, K.A., & Posner, G.J. (1992). A revisionist theory of conceptual change. In R.Duschl & R. Hamilton (Eds.) Philosophy of science, cognitive psychology, and educational theory and practice (pp. 147-176). Albany: State University of New York Press.

Time Magazine (March 8, 1993) Lunar mission (pp.21-22).

Vosniadou, S. (1987, April). Children's acquisition and restructuring of science knowledge. Paper presented at the annual meeting of the American Educational Research Association, Washington, DC.

Vosniadou, S. (1989). On the nature of children's naive knowledge. Proceedings of the 11th Annual Conference of the Cognitive Science Society, Ann Arbor, MI.

Vosniadou, S. (1992). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquistion in astronomy (Tech. Rep. No. 546). Champaign, IL: Center for the Study of Reading.

Vosniadou, S. , & Brewer, W.F. (1987). Theories of knowledge restructuring in development. Review of Educational Research, 57, 51-67.

Wolfman, I. (1991). My world. New York: Workman Publishing.

Wood, T. (1992). Our planet Earth. New York: Macmillan.