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# The Origin of Earth and Space Science Misconceptions: A Survey of Pre-Service Elementary Teachers

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## ABSTRACT

Understanding how misconceptions are formed can make it easier for classroom teachers to help their students uncover and overcome their misconceptions. Teachers, however, cannot be expected to help children uncover misconceptions if they hold these misconceptions themselves. This study attempts to discover which common misconceptions are held by pre-service elementary teachers and to what they attribute these misconceptions. A questionnaire containing several common earth and space science misconceptions was administered to 97 pre-service elementary teachers. A discussion of the concepts on the questionnaire followed during which participants were asked to reflect on their "incorrect" responses. Results from the survey are compared to an earlier cross-age survey conducted by the author in which the same questions were asked. The study suggests that many misconceptions originate in the classroom and that pre-service elementary education teachers have many of the same misconceptions that their future students will have.


## INTRODUCTION

Research over the last thirty years has shown that students and adults hold many alternative conceptions about the earth and sky. (Ault, 1982; Bar, 1989; Berg & Brouwer, 1991; Cohen & Kagen, 1979; Kuethe, 1963; Lightman, Miller & Leadbeater, 1987; Meyer, 1987; Nussbaum, 1979; Sadler, 1987; Schoon, 1992) Teachers can better prepare to help their students overcome their alternative conceptions if they are aware of which conceptions their students are likely to have.

It is in the elementary schools that many of the basic concepts about the earth and space are introduced. Therefore it follows that if students already have misconceptions about these concepts, it would be in the elementary schools that teachers should seek to help their students recognize and overcome them.

As early as 1972, Doran suggested that teachers should determine which misconceptions are prevalent among their students. Nussbaum and Novick (1982) showed that students should be made aware of their own conceptions. For students to alter their conceptions, they must then believe that their existing conceptions are unsatisfactory. Posner, Strike, Hewson, and Gertzog

(1982) proposed a conceptual change strategy: that for a new conception to be accepted, it must be intelligible, plausible and fruitful.

Many authors (Hewson, 1985; Anderson & Smith, 1987) have suggested that misconceptions are extremely resistant to change. Hewson (1981) has noted that students have and keep their alternative conceptions because they appear to make better sense to them than anything else. He and others have suggested strategies for helping students overcome their alternative conceptions.

Novak (1990) shows how the use of concept mapping can develop a greater conceptual understanding of science. Keig (1991) suggested that teachers pose problems which cause students to make connections between concepts. Strategies involving computer-aided instruction have been proposed by Zietsman and Hewson (1986) and others.

Wandersee (1985) noted that discussions of the history of science can help students overcome some misconceptions. In a similar vein, Griffith and Benson (1991), believing that knowledge is a process, argue that as a general teaching strategy, it might be more productive to trace the way that the understanding of concepts has changed, rather try to explain them.

Muthukrishna, Carnine, Grossen, and Miller (1993) noted from their research that it may not be necessary to take the time to individually address alternative frameworks in order to eliminate them. Their study, using a videodisc curriculum in eighth grade classrooms, resulted in 90% of misconceptions being eliminated without the alternative conceptions being addressed. Marek and Methven (1991) have shown how the learning cycle can be used to create a greater understanding of concepts, albeit with a lessening of content coverage.

It is unlikely that elementary teachers would be able to help their students address and revise alternative conceptions if they, themselves, hold the same alternative conceptions as their students. This study was undertaken to determine the extant to which pre-service elementary teachers hold alternative conceptions in the fields of earth and space science, and to what they attribute their alternative conceptions.

## METHOD

A survey was administered to 97 pre-service elementary teachers. The instrument used for this survey consisted of two sets of questions. The first set contained 18 multiple choice

questions. Following a format suggested by Gilman, Hernandez, & Cripe (1970), each question contained one correct, or scientifically acceptable answer, one or two common alternative conceptions, and other distracters to make a total of 4 options for each question. Each of these questions was followed by a set of reflection statements which were addressed during the second part of the survey's administration.

During the first part of the administration of the survey, the participants answered the questions on the instrument. Participants were all told that the survey was an attempt to discover and to reflect upon one's own alternative conceptions. Results from this part appear below in the section titled, "Results: Alternative conceptions held by pre-service teachers."

A few of the concepts examined in this survey, such as the direction of the sun at noon, are location-specific. In cases such as these, participants were told to answer the question from the viewpoint of northwest Indiana which is located at 41.5 degrees North latitude.

The second part of each administration consisted of a discussion and reflection which followed part one. As each question on the instrument and its common alternative conceptions were discussed, participants were asked to respond in writing to the second set of questions, namely:

a. I answered this one correctly.
b. I answered this one incorrectly, but it was only a guess.
c. I answered this one incorrectly because I thought that my answer was correct. I thought this because:

Responses which accompanied the third option were open ended explanations. Results from this second part appear in the second results section titled, "Results: The origins of the alternative conceptions."

Common alternative conceptions were identified in this study from those distracters which were chosen by more than 10% of the participants and chosen more than twice as often as the least common distracter.

## THE SAMPLE

The 97 participants in this study were students at Indiana University Northwest or at Purdue University Calumet, both located in urban Northwest Indiana. All of the participants were upper-level, elementary education majors who had completed most of the science courses

required for certification and a degree in elementary education. None of the participants had yet begun their student teaching practicum.

Reflecting the number of students who go through the elementary certification program in northwest Indiana, ninety-three percent of the participants were female and seven percent were male. Eighty-five percent of the participants were white, eight percent were black, and seven percent were Hispanic.

## RESULTS: ALTERNATIVE CONCEPTIONS HELD BY PRE-SERVICE TEACHERS

Results from this study have shown that pre-service elementary teachers hold many of the same alternative conceptions as their potential students. While reflecting upon their own misconceptions, many pre-service teachers attribute their misconceptions to hearing the misconception from another, who was often named as a teacher or group leader, to the media, or to logic or common sense.

Using a taxonomy of alternative conceptions suggested by Schoon (1992), five primary and twelve secondary alternative conceptions were identified as common in the pre-service teachers. "Primary Alternative Conceptions" are those which have been shown to be more prevalent than the scientifically acceptable conception. "Secondary Alternative Conceptions" are those which, though common, are less common that the scientifically acceptable conception.

It should be noted that a lower acceptance of a particular alternative conception does not necessarily mean a higher acceptance of the corresponding scientific conception. Therefore, in the tables below, which show the acceptance of the identified alternative conceptions, the acceptance of the corresponding scientific conception is also given.

The five primary alternative conceptions are listed in Table 1 in descending order of acceptance. The table compares the percentage of pre-service teachers holding each alternative conception with the percentage of 5th graders (n = 307) and all students, fifth grade through adults ( n = 1213) of the earlier study completed by the author (Schoon, 1992). Following each alternative conception are the percentages of acceptance of the corresponding scientific conception for the same three samples.

## Table 1.

## Acceptance of Primary Alternative Conceptions and Scientific Conceptions by Elementary Pre-Service Teachers Compared to Students in a Cross-Age Study

| Alternate Conceptions / Scientific Conceptions: | Percentage of Acceptance: Pre-service teachers | 5th graders | All ages |
|---|---|---|---|
| At 12:00 noon, the sun is directly overhead. | 85.6 | 69.4 | 82.4 |
| . . . the sun is in the south. [assuming 40° N latitude.] | 12.4 | 7.5 | 6.3 |
| Summer is warmer because the earth is nearer the sun. | 80.4 | 75.9 | 77.6 |
| . . . because the sun is higher in the sky. | 16.5 | 9.1 | 13.1 |
| Lunar phases are caused by the shadow of the earth. | 76.6 | 30.0 | 48.1 |
| . . . the lighted side . . . sometimes facing away. | 19.5 | 33.9 | 34.4 |
| When we have a full moon, Australia has a different phase. | 57.7 | 52.1 | 52.9 |
| . . . Australia also has a full moon. | 33.0 | 20.2 | 30.2 |
| In May, June, and July, the sun sets in the west. | 56.7 | 42.3 | 58.6 |
| . . . sets in the northwest. [assuming 40° N latitude.] | 20.6 | 21.8 | 18.6 |
| Shooting stars are stars that are falling. (1) | 28.9 | 22.8 | 24.0 |
| . . . are rocks that are falling. | 24.7 | 22.5 | 23.7 |

**Note**: (1) This alternative conception does not fit the predetermined limitations of a "common" alternative conception. However its high acceptance indicates that it may be as common as others in this study.

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The twelve secondary alternative conceptions are listed below in decreasing order of acceptance. Although some are subscribed to by a large percentage of the pre-service elementary teachers participating in this study, they were less common than were the corresponding scientific conceptions. The table extends for two pages.

## Table 2.
## Acceptance of Secondary Alternate Conceptions and Scientific Conceptions by Elementary Pre-Service Teachers Compared to Students in a Cross-Age Study

| Alternate Conceptions / Scientific Conceptions: | Percentage of Acceptance: Pre-service teachers | 5th graders | All ages |
|---|---|---|---|
| Planets can be seen at night only with binoculars or a telescope. | 40.2 | 50.8 | 41.5 |
| . . . because they are often brighter than . . . | 49.5 | 30.9 | 45.9 |
| It is not possible that in the near future Chicago could be severely damaged by an earthquake. | 28.9 | 31.6 | 36.5 |
| It is possible that . . . . | 71.1 | 64.5 | 61.6 |
| Shooting stars are the same as comets. (1) | 23.7 | 30.0 | 28.1 |
| . . . rocks that are falling down to earth. | 24.7 | 22.5 | 23.7 |
| Each day during summer the amount of daylight is more than the day before. | 20.6 | 31.6 | 32.4 |
| . . . less than the day before. | 54.6 | 10.1 | 25.8 |
| Dinosaurs lived at the same time as cavemen. | 19.6 | 31.9 | 32.6 |
| . . . lived long before cavemen. | 76.2 | 59.0 | 62.0 |
| It takes one day for the moon to go around the earth. (2) | 19.6 | 43.6 | 35.9 |
| . . . one month for the moon to go around the earth. | 68.0 | 20.5 | 42.3 |
| Terrible floods that occur along a river happen only when snow melts in the spring. | 17.5 | 38.1 | 33.6 |
| . . . can be caused by man. | 61.9 | 27.7 | 37.4 |
| The moon shines because it is like a star, just bigger. | 16.5 | 16.6 | 15.7 |
| . . . it reflects sunlight. | 75.3 | 65.8 | 70.8 |
| Day and night occur because the earth goes around the sun. | 14.4 | 24.4 | 19.6 |
| . . . because the earth spins on its axis. | 79.4 | 50.5 | 67.2 |
| Very cold winters can be predicted by seeing how hot it was last summer. (3) | 14.4 | 7.5 | 8.9 |
| Cold winters cannot be accurately predicted by . . . . | 73.7 | 64.2 | 73.3 |
| Very cold winters can be predicted by the thickness of fur on some animals in the fall. (3) | 12.4 | 17.6 | 12.0 |
| Cold winters cannot be accurately predicted by . . . . | 73.7 | 64.2 | 73.3 |

## Table 2. Continued

| Alternate Conceptions / Scientific Conceptions: | Percentage of Acceptance: Pre-service teachers | 5th graders | All ages |
|---|---|---|---|
| Earthquakes can be accurately predicted by observing the behavior of wild animals. | 12.4 | 17.6 | 15.4 |
| Earthquakes cannot be accurately predicted by . . . . | 79.4 | 61.6 | 74.1 |
| If a crystal can scratch glass, it is a diamond. | 11.3 | 54.4 | 44.4 |
| . . . it may be a diamond. | 76.3 | 32.2 | 47.1 |
| It takes one year for the moon to go around the earth. (2) | 11.3 | 30.3 | 19.5 |
| . . . one month for the moon to go around the earth. | 68.0 | 20.5 | 42.3 |

**Notes**:

(1) This alternative conception does not fit the predetermined limitations of a "common" alternative conception. However its high acceptance indicates that it may be as common as others in this study.

(2) These two alternative conceptions are related.

(3) These two alternative conceptions are related.

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## RESULTS: THE ORIGIN OF ALTERNATIVE CONCEPTIONS

Many factors contribute to the origin of the alternative conceptions identified by this study. Participants noted that it was difficult for them to "figure out why" they held various alternative conceptions.. In many cases, when asked to think about how they obtained, or why they held alternative conceptions, no comment or reason was given at all. In others, participants just noted that they had always thought [it] to be true. As noted below, four other common responses to this question were (1) being told (or taught) the alternative conception by others, often a teacher, or (2) figuring it out "logically," (3) the media, and (4) folk lore. Sadler (1987) noted that he found that students "overwhelmingly" attributed the origin of their astronomy alternative conceptions to schooling.

Table 3 shows the number of participants who attributed the origin of their alternative conceptions in each of seven categories: Taught in school, taught outside of school (this column

also includes those who do not indicate where it was taught), the media, logical reasoning, folklore, other reasons, and "Always thought it," which, unfortunately, does not give a origin.

## Table 3.
## Attributed Origins of Alternative Conceptions

**Alternate Conceptions:** **Number of Persons Who Atributed Alternative Conception to Each Type of Origin**

| | Percent Held | Taught: in school | school/ other | Media | Logical reason-ing | Folk-lore | Other | "Always thought" |
|---|---|---|---|---|---|---|---|---|
| At 12:00 noon, the sun is directly overhead. | 85.6 | 7 | 30 | 3 | -- | 4 | 7 | 8 |
| Summer is warmer because the earth is nearer the sun. | 80.4 | 11 | 5 | | 18 | -- | 13 | 8 |
| Lunar phases are caused by the shadow of the earth. | 76.6 | -- | 4 | -- | 2 | -- | 5 | 6 |
| When we have a full moon, Australia has a different phase. | 57.7 | -- | -- | -- | 7 | -- | 2 | 1 |
| In May, June, and July, the sun sets in the west. | 56.7 | -- | 16 | 2 | 2 | 6 | 6 | 4 |
| Planets can be seen at night only with binoculars or a telescope. | 40.2 | -- | 1 | 1 | 5 | -- | 2 | 2 |
| It is <u>not</u> possible that in the near future Chicago could be severely damaged by an earthquake. | 28.9 | -- | 1 | -- | 3 | 2 | 2 | -- |
| Each day during summer the amount of daylight is <u>more</u> than the day before. | 20.6 | -- | 1 | -- | 5 | -- | 7 | -- |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dinosaurs lived at the same time as cavemen. | 19.6 | -- | -- | 9 | -- | -- | 5 | 2 |
| It takes one day for the moon to go around the earth. | 19.6 | -- | -- | -- | 7 | -- | -- | -- |
| The moon shines because it is like a star, just bigger. | 16.5 | -- | 1 | -- | 1 | -- | -- | 1 |
| Day and night occur because the earth goes around the sun. | 14.4 | 1 | 1 | -- | -- | -- | 3 | -- |
| Very cold winters can be predicted by seeing how hot it was last summer. | 14.4 | -- | 3 | -- | -- | -- | -- | -- |
| Very cold winters can be predicted by the thickness of fur on some animals in the fall. | 12.4 | -- | 1 | -- | -- | 7 | -- | -- |
| Earthquakes can be accurately predicted by observing the behavior of wild animals. | 12.4 | -- | 3 | 2 | -- | 3 | -- | 2 |
| If a crystal can scratch glass, it is a diamond. | 11.3 | -- | 1 | -- | 1 | 5 | 4 | -- |
| It takes one year for the moon to go around the earth. | 11.3 | -- | -- | -- | -- | -- | 4 | -- |

**Note:** Several persons noted they were taught the alternative conception but did not state where. These are included in: Taught: School/Other

For each alternative conception chosen, participants were asked to reflect upon whether the choice was merely a guess or whether the choice reflected an actual conviction. If an actual conviction, the participants were then asked to reflect upon how the particular alternative conception was acquired.

Although data concerning guessing was collected, it is biased in that the participants were asked to note this only after they were told the scientific conception. Guessing was claimed from five to fifty percent of the participants, depending on the concept involved. The mean percentage attributed to guessing was 21.1%, or roughly one in five participants per question. The author believes that this percentage is artificially high.

Results concerning the origin of alternative conceptions are grouped below by general subject area.

## Sun - Earth Relationships

Alternative conceptions related to the sun - earth relationship fall into two categories: A misunderstanding of the daily and annual patterns made by the apparent motion of the sun, and, alternative conceptions concerning the revolution of the earth around the sun. Those in the first category are truly misconceptions in that the scientific conception is not based upon theory, but upon observation and measurement. These are quite different from scientific conceptions based upon observation and inference such as the cause of seasons. Common alternative conceptions in the first category include:

| | |
|---|---|
| At 12:00 noon, the sun is directly overhead. | 85.6% |
| In May, June, and July, the sun sets in the west. [as opposed to northwest] | 56.7% |
| For each day of summer the amount of daylight is more than the day before. | 20.6% |

Common alternative conceptions in the second category include:

| | |
|---|---|
| Summer is warmer than winter, because the earth is nearer the sun. | 80.4% |
| Day and night occur because the earth goes around the sun. | 14.4% |

The acceptance of the sun's being straight up at noon by 85.6% of pre-service elementary teachers mirrors the general acceptance of that alternative conception across all ages. It demonstrates that even if the existence of the Tropic of Cancer is known, its significance often is not. Most participants (68%) attributed this belief to their previously being told by others that it was true. Others (13.6%) merely noted that they had always thought that it was straight up. Seven respondents stated that they learned it in school, while others attributed it to a parent, a scout leader, cowboy movies or cartoons. The phrase "high noon" was mentioned

by several participants. One participant noted that in sign language for the deaf the sign for noon points straight up. (See Riekehof, 1963) One student lamented, "No one ever told me otherwise, so I never thought to look."

The two other misconceptions in this category are both concerned with the annual pattern of solar movement. The phrase, "the sun rises in the east and sets in the west," as useful as it is to explain much about solar movement, has apparently resulted in the erroneous belief that the sun rises exactly in the east every morning and sets exactly in the west every evening. As with the alternative conception concerning the sun's being straight up at noon, most respondents (65.8%) attributed their belief to either their being taught this misconception, hearing it referred to in movies, or hearing the phrase mentioned above.

That many participants (20.6%) believed that daylight increased through the summer was attributed to the longer days of summer. Many of the participants were just unaware of the annual pattern of daylight length; five participants specifically gave this explanation. No one attributed this misconception to being told it by someone else.

Summer's being warmer than winter because the earth is nearer to the sun was subscribed to by more than 80% of the pre-service teachers surveyed. This is similar to the results demonstrated in the video, *A Private Universe,* (Harvard-Smithsonian Center for Astrophysics, 1985). Forty-seven percent of those who gave reasons for their alternative conception claimed it was a result of logical reasoning or that they had just "always" believed it to be true. Twenty-nine percent attributed this to their being taught this in school or hearing it from other persons. Many persons noted that they thought the "correct answer," the tilting of the earth, was not among the choices on the instrument. [The scientific conception was worded as . . . "the sun is higher in the sky".] Many participant's responses can be attributed to a mixed-conception: The tilt of the earth often causes one hemisphere to be closer to the sun than the other, this relative closeness is the cause of the warmer summer weather. Typical is the response, "I thought that because the hemisphere of the earth which faces the sun is having summer, that the earth would then be closer to the sun."

Day and night being caused by the earth going around the sun was subscribed to by a small number of participants (14.4%) Representative of those with this conception was, "I knew that the earth goes around the sun which to me means *the same as* or similar to the earth spins on its axis. " Two of the six persons who gave reasons for their alternative conception stated that they were taught it this way.

## Moon - Earth Relationships

There were five common alternative conceptions identified which were related to the moon - earth relationship. Four of them were related to the revolution of the moon around the earth and the resultant phases seen from the earth. They were:

The phases of the moon are caused by the earth's shadow falling on the moon. 76.6%

When we have a full moon, people in Australia will have a different phase of the moon. 57.7%

It takes one day for the moon to go around the earth. 19.6%

It takes one year for the moon to go around the earth. 11.3%

The other alternative conception concerns what it is that makes the moon shine:

The moon shines because it is like a star, just bigger. 16.5%

The phases of the moon being caused by the earth's shadow falling on the moon was the third most common alternative conception identified by this study (at 76.6 %). The pre-service elementary teachers had a much higher acceptance of this alternative conception than did the 5th graders surveyed earlier, although about a third (29%) of the participants who chose this conception claimed that they had guessed in choosing it. Kuethe (1963) found that 70% of his subjects had this alternative conception. Sadler (1987) found that 37% of his ninth grade students also had this belief. In explaining the origin of their alternative conception, most participants claimed that they had simply always believed it to be true and/or that their belief seemed logical. Some inferred that since the earth's and sun's shadows caused eclipses, shadows were also responsible for lunar phases.

What phase of the moon can be seen from Australia when there is a full moon over the U.S.? No question on the instrument resulted in more guessing than this one (51%). Most students who volunteered comments about this concept noted that they had never considered it before. Ault (1984a) noticed the same reaction in describing how his science education graduate students struggled when asked this question. However, 57.7% of the participants in the current study believed that it would not be a full moon. Typical of justifications for their responses were, "I thought all parts of the world see different phases of the moon" and, "Because I know that Australia has opposite seasons, so I also thought they had opposite phases of the moon."

The length of the lunar revolution around the earth was the subject of two related alternative conceptions. Nearly one in five participants (19.6%) believed the moon completed a revolution every day. This belief was attributed to the daily rising and setting of the moon

by 70% of the respondents. A much smaller percentage, 11.3%, believed the revolution to be annual. No real justifications for this conception were given. Combining the percentages of the two alternative conceptions shows, however, that 30.9% of prospective teachers are apparently unaware that the monthly change in lunar phases is caused by the monthly revolution of the moon.

The moon shining because it is like a star, just bigger, was subscribed to by 16.5% of the participants. Too uncommon to be included above as a common alternative conception is the belief that the moon shines because it makes light like the sun, which was professed by 8.2%. These two similar alternative conceptions were selected by nearly 25% of the participants, showing that the concept of luminosity may just not be well understood by these persons. One participant noted, "I assumed since it [the moon] shined like the sun, it made it own light like the sun." Guessing was admitted by most of the participants who did not know the scientific conception. However, no participant chose a fourth explanation: The moon is so hot it glows.

## Planets and Meteors

Over 40% of the pre-service teachers subscribed to the alternative conception that planets can be seen at night only with a telescope or a pair of binoculars. Although many participants claimed that they had just guessed, very few (less than 5% each) chose the two other options: Planets can be seen only after midnight or that planets are in the same place in the sky every night. Of those who claimed to have believed that planets could only be seen with optical instruments, several justified their belief by the fact that planets are so far away. One participant noted that, "People as seen on TV use a telescope to view the stars and planets. " Another noted that, "I figured you could not [see them] without a telescope."

The fact that many advances in astronomy have been made through the use of instruments such as the telescope may have contributed to the popularity of the alternative conception that planets can be seen at night only with a telescope or a pair of binoculars. All participants in this study lived in or near the northwest corner of Indiana not far from Chicago. The abundance of buildings, trees, smog and light which can all obscure the night sky makes it difficult for even the most motivated person to view the heavens at night.

The survey showed that falling or shooting stars are not well understood by many pre-service elementary teachers. Not one of the alternative conceptions was chosen more than twice as often as the least chosen option, and therefore, whether any of the alternative conceptions listed here are very common is not known. Nearly two-thirds (63%) of those

choosing any of the alternative conceptions claimed to have guessed. That shooting stars are stars that are falling was subscribed to by 28.9% of the participants while falling stars being the same as comets was professed by 23.7%. In justifying their responses, several participants noted that they had been taught that falling stars were stars that were falling to the earth. One participant claimed to have read it in a book.

## Physical / Historical Geology

Five alternative conceptions are in the realm of physical or historical geology. However, none of these alternative conceptions, which were related to the geologic range of dinosaurs, earthquakes, flooding, and the identification of diamonds by hardness, were subscribed to by more than 30% of the participants. Guessing appears to have played a smaller part in the physical or historical geology conceptions chosen than in other areas.

More location specific than many of the questions in this survey, the alternative conception that it is not possible that in the near future [nearby] Chicago could be severely damaged by an earthquake was selected by 28.9% of the participants. In fact, the midwest was the site of one of North America's largest earthquakes. But that was 180 years ago and apparently unknown to many midwestern residents. Typical of justifications for the alternative conception was, "Because we are not on a major fault line " and "We are not in the earthquake belt or a place where earthquakes are possible." Few participants (11%) claimed to have been guessing when choosing this alternative conception.

That dinosaurs lived at the same time as cavemen was subscribed to by 19.6% of the participating pre-service elementary teachers. Justification for this alternative conception was attributed to movies and books and to the popular cartoon, "Flintstones." One participant noted that, "I was always a Flintstones fan, and have always believed they lived at the same time." Participants seemed rather sure of their thoughts concerning dinosaurs. Of all the alternative conceptions identified by this study, guessing played the smallest part (at 5%) for this one. This survey was completed before the distribution or even the advance publicity for the film, "Jurassic Park."

That earthquakes can be accurately predicted by observing the behavior of wild animals was professed by 12.4% of the participants. Although none of them gave specific reasons for professing this, many referred to having read or heard something like this. Few (8%) admitted to guessing.

Folklore claims that one can identify a diamond by seeing whether it can "cut" glass. This is in part responsible for the fact that 11.3% of the participants subscribed to the misconception that if a crystal can scratch glass, it is a diamond. Typical of the justification was, "You always hear that only a diamond scratches though a glass." The confusion between "cut" and "scratch" was noted by four participants as the reason for choosing the misconception. Few of the participants (8%) claimed to have guessed.

The 1993 flooding in the Mississippi River valley had not begun when this survey was conducted. One can assume that the number of persons with this misconception has decreased with the occurrence of that flood. Never-the-less, at the time that this survey was conducted, 17.5% of the participants subscribed to the belief that the terrible floods that occur along a river happen only when snow melts in the spring. However, a large percentage of respondents (24%) did claim that their response was a guess.

### Weather Prediction

Two similar alternative conceptions concerned with weather prediction were identified by this study: That very cold winters can be accurately predicted by seeing how hot it was during the previous summer (subscribed to by 14.4% of the participants), and by looking at the thickness of fur on some animals in the fall (subscribed to by 12.4% of the participants). Justifications for these two alternative conceptions were very similar; all had read or heard it from someone else. Kimble (1955) attribute the prediction of a cold winter by examining fur as part of American folklore. One person called it an old wive's tale, another claimed that, "My Native American friend is in tune with nature and told me this." Fourteen percent claimed to have been unsure and so guessed.

## IMPLICATIONS

This study has shown that pre-service elementary teachers attribute many of their alternative conceptions to their being taught, both in and out of the classroom. Other sources of alternative conceptions are the media (print, film, and television), folk lore, and from what students called logical reasoning. Ault (1984b) has shown that misconceptions of children are often the result of imaginative and very perceptive thinking. Adults often form alternative conceptions in the same way. The study also showed that many of these pre-service teachers have many of the same alternative conceptions as their future students are likely to have.

Children do form alternative conceptions in the classroom. This was shown by the participants in this study who attested to their having non-scientific views of concepts explained to them in school, particularly in the space sciences. This is similar to, but not as dramatic as, Sadler's work (1987) where students were found to have "overwhelmingly" attributed the origin of their astronomy alternative conceptions to their experiences in school.

Osborne, Bell, and Gilbert (1983) found that many primary teacher trainees have a rather negative attitude toward science. This is similar to attitudes of many pre-service elementary teachers noted informally by the author. If a negative attitude and alternative conceptions in science are carried with teachers into the classroom, this may explain the development of alternative conceptions in the minds of children while in the classroom. Osborne, Bell, and Gilbert (1983) noted that science taught in schools is often a mixture of the teacher's own views and textbook quotations.

Shymansky, Yore and Good (1991) suggest that, although elementary teachers seem to perceive a need to provide a hands-on curriculum, they still place great importance on content coverage and preparation for the next grade. The race to complete a set curriculum often results in a skimming-over of content and little in-depth study. Students learn that there is a Tropic of Cancer but have no idea of why such a line exists.

Clearly teacher preparation programs must attack the alternative conceptions of its candidates.

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