Preservice Elementary Teachers' Conceptions of the Causes of Seasons

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Abstract

This study used both a written procedure and a procedure of models with verbal explanation to investigate 49 preservice elementary teachers' conceptions of what causes the seasons. Only one person each provided a response on each procedure which reflected a scientific conception. A total of 39 students provided alternative conception responses on the written procedure; 42 students provided responses judged to reflect alternative conceptions on the models with verbal explanation procedure. The distance of the earth from the sun was the most commonly expressed alternative conception on both procedures. Many students were not consistent in providing a particular alternative conception for the two procedures, which indicates that the alternative conceptions expressed may not be firmly held.

The term *alternative conception* has been used to describe a conception which is inconsistent with currently accepted scientific views (Dykstra, Boyle, & Monarch, 1992; Hills, 1989). It has been shown (Aron, Francek, Nelson, & Bisard, 1994; Atwood & Atwood, 1995; Bitner, 1992; Feher & Rice, 1987; Galili, Bendall, & Goldberg, 1993; Gilbert, Osborne, & Fensham, 1982; Glasson & Teates, 1989; Heller & Finley, 1992; Lane & French, 1994) that preservice and inservice elementary teachers hold alternative conceptions for a variety of science concepts. However, they are not alone among college students and college graduates in holding alternative science conceptions. Schneps (1988) revealed that only 2 of 23 students selected at random from a graduation line at Harvard in 1987 could provide a scientific explanation for why it gets hotter in the summer than in winter. Hazen and Trefil (1991) cited this result as evidence of a scientific literacy problem in the United States.

A survey of the elementary science textbooks of seven publishers (Heath; Scott-Foresman; Holt; Merrill; Harcourt, Brace, Javonovich; Silver Burdett & Ginn; and Macmillan) revealed that five provide information on the causes of seasonal change. This information, plus the investigators' own experiences in schools, suggest that attempting to teach elementary children about the causes of seasons is not an uncommon practice. While holding an alternative conception of what causes the seasons could be viewed as a regrettable lack of scientific literacy for any adult, it would be a much more serious problem for teachers who could be expected to help students construct a scientific understanding of this phenomenon. This study sought to take a major step toward addressing the problem by investigating two questions: First, are alternative conceptions on the causes of seasons frequently held by preservice elementary teachers? Lacking a basis for expecting preservice elementary teachers to have had more opportunity and

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motivation to develop scientific conceptions than the sample of 1987 Harvard graduates (Schneps, 1988), it was predicted that a high frequency of alternative conceptions of the causes of seasons would be found. Assuming that prediction would be supported, a second question—What are the alternative conceptions frequently held?—was investigated. It was reasoned that the results of the study not only could help establish a need for instruction on this topic but also could inform instruction aimed at helping preservice elementary teachers construct a scientific conception of what causes the seasons.

Methodology

To obtain the data needed for this descriptive study, two different procedures were used. First, 49 preservice elementary teachers (students) were asked to respond in writing to the question, What causes the seasons for regions of the earth that experience winter, spring, summer, and fall? The question for the written procedure was posed during a class session of a science methods and materials course. The students were told that their responses would be useful to the instructors in providing more effective instruction, and responses would not be used in determining course grades. This will be called the *written procedure*. Second, during individual interviews over the 2 subsequent days, each student was asked to use simple models of the earth and sun to demonstrate what causes the seasons, while giving a verbal explanation. The content of the interviews was not announced in advance, and each interviewee was asked to refrain from discussing the content or procedures of the interview with others. This will be called the *models with verbal explanation procedure*.

Although both procedures yielded data to answer the research questions, the written procedure appeared to tap declarative knowledge and the models with verbal explanation procedure appeared to tap procedural knowledge (Lefrancois, 1988). Thus, data obtained using the two procedures were expected to provide insights beyond those provided by either procedure alone.

Subjects

The 49 students in the sample were enrolled in a senior-level block of professional course work at a major university in the midwestern United States. All students in the sample were Caucasian, and 48 were female. The students received no instruction in any course on the causes of seasons, or related astronomic phenomena, during the semester in which the research was conducted. Science and social studies methods and materials courses were part of the professional block. General studies requirements, including a minimum of 15 hr of social science and a two-semester sequence with laboratory in both the physical and biologic sciences, had been completed prior to the semester in which the interviews were conducted.

Models

Although the models used for the models with verbal explanation procedure were crude in many ways, including scale, they were similar to models one of the investigators had observed a middle school science teacher use with positive commentary during a staff development session for middle school teachers. On that occasion, participating middle school teachers made positive comments about the usefulness of the models for aiding their own understanding of the phenomenon. In a follow-up discussion, none of the teachers offered an alternative approach thought to be more promising. The sun was represented by a yellow sphere approximately 7 cm in diameter; the sphere rested in a cradle, which was a plastic germinating cup base. The earth was represented by a white Styrofoam sphere approximately 4 cm in diameter. Inserted through the center of the white sphere and into one of two holes in a small wooden block was a wooden dowel rod approximately 10 cm in length and 3 mm in diameter. When the dowel rod was inserted in one hole, the rod and model of the earth stood perpendicular to the horizontal surface. When the rod was inserted into the other hole, the rod and model of the earth stood tilted approximately 23.5° from perpendicular. In either case, the fit of the dowel was just loose enough to be easily rotated. An ink longitudinal line was drawn around the sphere, ending where the dowel rod emerged from either pole of the sphere. An ink latitudinal line was drawn around the sphere to represent the equator. A straight pin inserted in the Styrofoam "earth" was used to indicate the approximate location in the northern hemisphere of the city in which the students attended college and the interviews were conducted.

Interviews for Models with Verbal Explanation Procedure

At the beginning of each interview, a student and one of the principal investigators were seated at a 4-ft square, flat-top table. The model of the sun was located in the center of the table and two models of the earth, one with the dowel rod perpendicular to the horizontal base and one with the dowel rod tilted approximately 23.5°, were located near the student. The yellow sphere was introduced as a crude model of the sun, and the Styrofoam spheres were introduced as two crude models of the earth. The locations of the poles, equator, and city were identified on both models for the student.

At this point, the student was asked to choose one of the models of the earth and use it and the model of the sun to show, while verbally explaining, what causes the seasons for regions of the earth that have summer, fall, winter, and spring. When one of the models of the earth had been chosen, the other model of the earth was removed from the table and placed out of sight. In responding to the task, several students picked up the model of the earth or sun, or both, from the table and moved the models closer to each other. Some students moved one of the models to a different plane. No attempt was made to restrict the movement of the models.

If the response provided by the student clearly represented a scientific conception (SC) or alternative conception (AC), the investigator responded with "Okay", or "I see," or repeated part of the student's concluding statement as might be done to verify that one has heard correctly. It was thought that probing a response which had been clearly stated might be interpreted by the student as indicating that the response was unsatisfactory and encourage on-the-spot framing of a new explanation. Responses which were not clearly SC or AC were gently probed with expressions such as "Say more about that," or "I'm not sure I understand; now what causes the seasons?"

In an extension which served as a uniform probe of the models with verbal explanation procedure, each student was asked to use the models to illustrate summer in a designated hemisphere (i.e., northern or southern) and then to show with the models what would happen over time as the season changed from summer to winter in that hemisphere. The extension probe provided the student with an opportunity to apply the understanding which had been shown and explained. Thus, the student's response on the extension probe served as a validity check of the response on the models with verbal explanation procedure. The results of a pilot study conducted during a previous semester were useful in structuring the interview and a form (see Appendix) for reporting and classifying student responses.

Based on the pilot study, the investigators judged it easy to classify responses into SC or AC categories at the time of the interview for the models with verbal explanation procedure. Obviously the no response (NR) classifications also were easy to make, as in these cases students simply declined to attempt the task. Based on the pilot, only a small number of responses were expected to be classified as incomplete (IR) or unclear responses (UR), which proved to be the case. Considering these factors and the concern that a videocamera and operator would have been intimidating and distracting, the interviews were not videotaped.

For the first 11 interviews, the two investigators alternated between conducting an interview and observing one. Both investigators independently completed a response form for each of these 11 interviews. Recorded responses and classifications were compared after each interview. There were no consequential differences in recorded notes on explanations and actions of students and no differences between investigators' classifications of students' conceptions. Subsequent to establishing consistency in rating, each investigator interviewed half of the remaining 38 students, thus limiting the total interview time to 2 days. The rationale for this condensed schedule was to discourage instruction on the tasks between students.

Classification Criteria for Responses

Criteria for determining whether a response on either procedure reflected a scientific conception were based on the following explanation from Rutherford and Ahlgren (1990):

> The earth's one-year revolution around the sun, because of the tilt of the earth's axis, changes how directly sunlight falls on one part or another of the earth. This difference in heating different parts of the earth's surface produces seasonal variation in climate. (p. 38)

Thus, for a student's response to be classified as reflecting an SC on either procedure, it had to include an explanation of how the tilt of the earth on its axis as it revolves around the sun causes different heating effects. In addition, for a response to be classified SC for the models with verbal explanation procedure, the student had to give scientific responses on the extension probe. A response which clearly was at odds with a scientific explanation was considered to reflect an alternative conception and was classified as AC. A response was classified as incomplete explanation (IE) if the response included only one or two of the factors of earth's tilt, earth's revolution, or differential heating effects and no evidence of an alternative conception. NR was used when no response was attempted on the written procedure or when the student declined to attempt any part of the models with verbal explanation procedure. Unclear responses, which did not meet the SC, AC, IE, or NR criteria, were classified as UR.

Results and Discussion

Table 1 shows results for the two procedures. An important finding was that a high percentage of students gave one or more responses which reflected an AC on both the written procedure (79.6%) and the models with verbal explanation procedure (85.7%). For each of the two procedures, only one person each met the criteria to have a response classified as expressing an SC. These results for a sample of preservice elementary teachers are consistent with the findings reported by Schneps (1988) for a sample of college graduates selected without regard for academic specialization.

Written Procedure Results

A total of 39 students provided 44 AC responses on the written procedure; each of 5 students provided two AC responses. In addition, 16 different alternative conceptions were

Table 1
Frequencies of Categorization of Preservice Elementary Teachers' Responses Based on the Question, What Cause the Seasons?

Response categories	Written procedure	Models with verbal explanation procedure
SC	1	1
AC	39	42
IE	6	0
UR	2	4
NR	1	2

Note. SC = scientific conception; AC = alternative conception; IE = incomplete explanation; UR = unclear response; NR = no response.

expressed in the 44 written AC responses. Only 4 of the 16 different alternative conceptions were expressed by more than one student. A list of the conceptions and number of students giving each follows:

- the distance of the earth from the sun (18)
- the closeness of part of the earth due to the earth's tilt (6)
- the rotation of the earth on its axis (4)
- the way the earth is positioned on its axis; the part facing the sun is having summer (4).

Note that 24 written AC responses attributed seasonal changes to the distance of the earth from the sun. Of these, 18 students attributed the effect to distance in a general way, perhaps thinking of an effect of the earth's elliptical path around the sun. Two examples of these written responses on the cause of seasons are:

1. "The distance of that part of the earth from the sun which is caused by the earth moving around the sun"
2. "The way in which the earth revolves so that at different times of the year the different regions of the world are at different distances from the sun, creating different seasons."

Six students attributed importance to variation in distance as a result of the earth's tilt. A response typical of these six was, "The seasons are caused by the tilting of the earth's axis toward and away from the sun. While it is winter here, we are farther away from the sun, but some places on earth are closer to the sun so it is summer there." For these six cases, the thinking seemed to be that when part of the earth is tilted toward the sun, it is closer to the sun, and thus gets hotter; and when part of the earth is tilted away from the sun, it is farther from the sun, and thus gets colder. Either view involving distance could reflect a commonsense construction (Hills, 1989).

Four written AC responses attributed the seasons to the rotation of the earth on its axis. One student whose response was classified in this category suggested that the seasons are caused by the "rotation of earth and air flow streams like the jet stream." Because it is not clear from the response how strongly the student related rotation of the earth and air flow streams, this student's response was considered to include two alternative conceptions. No other students relied on air flow streams or jet streams in providing explanations. Four other students who indicated that the part of the earth facing the sun would be having summer also may have been thinking about an effect due to the earth's rotation. A sample response follows: "The tilt and spin of the earth causes the seasons. When we have winter in [the city in which we are located], that part of the earth is turned farthest away from the sun, causing it to be cold here." Although this student began the statement by identifying both tilt and spin as causes, the remainder of the statement seems to elaborate on how spin affects the seasons. Another plausible interpretation is that the student was thinking about the northern or southern hemisphere receiving more light or heat because of the earth's tilt.

Models with Verbal Explanation Procedurė Results

It was interesting to note that 38 of 49 students selected the tilted model of the earth for this task. This choice suggests that a large percentage of the sample had declarative knowledge that the earth is tilted on its axis. Unfortunately, that knowledge did not prove to be functional for showing and explaining the causes of seasons. A total of 42 of 49 students (85.7%) provided 45 responses which were judged to reflect an AC; 3 students provided two AC responses. Of the 11 different AC responses verbally expressed and/or demonstrated, the distance between the earth and the sun again was provided most frequently. A list of the five different AC responses given by more than one student and the frequencies of the responses follow:

- the distance of the earth from the sun (19)
- the direction of the earth's tilt changes as the earth revolves around the sun (7)
- the rotation of the earth on its axis (6)
- the pole of the hemisphere having summer is pointed almost directly toward the sun (4)
- the sun revolves around the earth (3).

The examples of student responses which follow are intended to provide insight into how the Investigators' response form was used during the interviews, and to illustrate the categorization of responses. One student began this task by indicating that the sun was closer to the earth in summer, and she changed the tilt of the earth model as she started to revolve it around the sun. Suddenly she stopped, stared at the models for a few seconds, and then provided a verbal response and demonstration which indicated how the tilt of the earth as it revolves around the sun produces different heating effects to cause the seasons. At this point, she removed her hands from the models and looked at the investigator, indicating that she had completed a response to the instructions. The investigator, who had been silently observing and recording, asked her to explain and show that again. Without hesitation, the student again provided the SC response and only the SC response. The investigator replied "I see," and circled earth's tilt, earth's revolution, and intensity on the investigators' response form, indicating that these three elements had been appropriately included in the student's response. Moving to the extension probe, the investigator asked the student to use the models to represent summer in the southern hemisphere. Prior to beginning the interviews, the response sheets had been randomly marked to direct the investigators as to which hemisphere to use in the probe. The student moved the model of the earth in a position to maximize the tilt of the southern hemisphere toward the model of the sun. The investigator circled Yes on the form and asked the student to show with the models what would happen over time in going from summer to winter in the southern hemisphere. The student moved the model of the earth in a circular pattern approximately 180° around the model of the sun. In doing so, she maintained the direction of the tilt of the model of the earth so that when she had completed the task, the tilt of the southern hemisphere was maximized away from the model of the sun. The investigator responded with "Okay," and asked the student whether in winter the sun is the same distance from the earth, farther or closer than in summer. The order in which the investigator gave the three options also had been randomly marked on the forms prior to the interviews. The student responded that the sun is approximately the same distance, and any difference in distance is not important in determining seasons. No probing of responses in the extension was judged to be necessary, because the entire extension was viewed as a probe of the student's initial response to the models with verbal explanation procedure. After the student responded to the question about when she last had formal instruction on this topic, she was reminded not to discuss the interview with classmates, and was dismissed. The investigator then completed any additional notes judged to be important, reflected on the student's performance, and classified the student's responses as reflecting an SC. Considering the student's aborted false start and subsequent performance, it was inferred that the models likely had some instructional value for her.

Another student moved the model of the earth in an obviously elliptical path around the model of the sun, stopping when the models were relatively close to each other, and indicated that this would be summer because of the shorter distance. She stopped again when the models were relatively far apart and indicated that it would be winter because of the longer distance between the earth and sun. The investigator replied "Okay," and moved to the extension probe. The student stuck to the distance thesis, ignoring the tilt, in completing the two tasks of the extension probe. When asked specifically about the distance between the earth and the sun in winter, the student replied that the sun is farther away in winter. The student's performance was classified as reflecting an AC.

For the extension probe of this procedure, 24 of 49 students (49%) correctly positioned the models to represent summer in the designated hemisphere. However, only one, the only SC respondent on this procedure, correctly demonstrated what would happen over time in going from summer to winter for the designated hemisphere. Perhaps this finding means that 49% of the sample could use their knowledge of the tilt of the earth to represent summer or winter, but most of the sample did not understand either the constancy of the earth's tilt as the earth revolves around the sun or how the tilt, in conjunction with the earth's revolution, produces differential heating effects, or seasonal change.

Comparison of Results from the Two Procedures

As reported earlier, no student demonstrated an SC on both procedures. The student providing an SC response on the written procedure changed the tilt while revolving the model of the earth around the sun during the extension probe. The student whose response was classified SC on the models with verbal explanation procedure had written that the cause of the seasons was the distance of the earth from the sun as the earth moved in an elliptical path around the sun. As previously suggested, the models may have had instructional value for her. It seems apparent that neither student had firmly held an SC before engaging in the two assessment procedures, and at best, only the student providing an SC response using the models held an SC after completing both procedures. No responses were classified as IE (incomplete response) on the models with verbal explanation procedure, compared with six on the written procedure. Perhaps this difference can be attributed to the use of the probing option with interviews which was not available for the written procedure.

Although the lists of alternative conceptions identified by the two procedures appear to be similar and the numbers of particular AC responses provided on both procedures differ little, relatively few students revealed the same AC on both procedures. For example, the most frequently expressed AC on both procedures was the distance of the earth from the sun; however, only 6 students of a possible 18 gave that response on each of the two procedures. Further, none of the six students who verbally explained and demonstrated that the rotation of the earth on its axis was the cause of seasons gave that explanation on the written procedure. Clearly, the use of two procedures did provide insights not provided by either procedure alone. Specifically, the use of the two procedures revealed an inconsistency in alternative explanations which would not have been revealed by the sole use of either procedure.

Alternative conceptions in some cases have been shown to be firmly held (Boyle & Maloney, 1991; Brown, 1992; Champagne, Klopfer, & Anderson, 1980; Schoon, 1989). The inconsistency of the alternative conceptions expressed by individuals across the two procedures used in this study suggests this was not one of those cases. Perhaps these students were showing evidence of a largely untutored conception (Hills, 1989) rather than strong effects of ineffective or misleading instruction (Cho, Kahle, & Nordland, 1985; Gilbert & Zyberstajn, 1985). The self-reports of when the cause of seasons previously had been studied provide support for the inference that these were largely untutored conceptions. A total of 12 of the 49 students could not recall ever having studied the topic; 6 others were emphatic in reporting that they had never studied the topic at any level of schooling. For the other 31 students, frequencies of prior study by level, including reports of study at more than one level, were: elementary, 16; junior high/middle school, 14; high school, 6; and college/university, 7. Thus, if instruction of some form had been provided, for most students it had not been provided recently.

Conclusions and Recommendations

With respect to the first research question, as predicted, students in the sample frequently held alternative conceptions of the causes of seasons. This finding, with some corroboration from Schneps (1988), suggests that other groups of preservice elementary teachers also are likely to show a high frequency of alternative conceptions of what causes the seasons. This problem should be addressed. First, the question of how important it is for elementary teachers to have a scientific understanding of the causes of seasons should be considered from the perspectives of scientific literacy and elementary teachers' instructional responsibilities. Hazen and Trefil (1991) lamented the fact that "Americans as a whole simply have not been exposed to science sufficiently or in a way that communicates, the knowledge they need to have to cope with the life they will have to lead in the twenty-first century." (p. xv). Clearly, Hazen and Trefil, as well as Rutherford and Ahlgren (1990), supported the view that an understanding of the causes of seasons is part of scientifically literacy. Focusing on elementary teachers' instructional responsibilities, it is noteworthy that innovative, hands-on elementary science programs such as SCIS-3 and Science and Technology for Children do not include the causes of seasons. Developers of these programs likely chose to focus on topics which children more easily can investigate directly and which arguably are more developmentally appropriate topics. However, the fact that information on the causes of seasons is included in five of seven elementary science textbook series surveyed by the investigators suggests that it reasonably could be, and perhaps should be, viewed as part of elementary teachers' instructional responsibilities and addressed in preparation programs for elementary teachers. Perhaps teacher preparation programs should address the reality of contemporary instructional expectations while advocating a movement away from depending on textbooks and topics which are marginal to inappropriate from a developmental perspective.

Results obtained in pursuing the second research question—identification of alternative conceptions frequently held—should be useful to persons who decide to address the causes of seasons in elementary teacher preparation programs. Specifically, planners of instruction should anticipate needing to confront those alternative conceptions which were expressed by several students in this study. The models with verbal explanation procedure, which requires a performance that shows the abiltiy to use procedural knowledge, is recommended to determine whether the alternative conceptions frequently identified in this study also are observed frequently in other samples of elementary preservice teachers.

Results which suggest that preservice elementary teachers' conceptions of the causes of seasons are not firmly held and may be largely untutored should be encouraging to instructional developers. A relatively brief period of instruction which targets the alternative conceptions frequently held could produce very positive results; it is recommended that this possibility be explored. Having observed the models being used with positive reviews in a staff development session for middle school science teachers and having seen limited evidence in this study that the models can have instructional value, we recommend that low-budget instructional efforts include the use of the models. A computer simulation which shows the differential heating effects caused by the tilt of the earth on its axis as it revolves around the sun could be a valuable, but more expensive, alternative instructional tool. Graphics illustrating the movement of the earth around the sun should show that the very small variation in the path from a circular orbit is not responsible for the differential heating effects and should demonstrate what is responsible for them. Development of an effective computer simulation for this purpose could be an important contribution to science education, and is recommended.

The contention (Gunstone, Gray, & Searle, 1992; Hewson, 1981; Posner, Strike, Hewson, & Gertzog, 1982) that science instruction aimed at promoting conceptual change should be viewed by the student as being intelligible, plausible, and fruitful should be taken seriously by those who design instruction to address this problem. It is anticipated that instruction using either the models described in this study or a computer simulation will prove to meet the intelligible and plausible criteria. Making prospective elementary teachers aware of the frequency with which the causes of seasons is addressed in elementary science textbook series could influence them to view the study as being fruitful.

Appendix: Investigators' Response Form

Student's name________________________________

Choose a model of the earth and use it, along with the model of the sun, to show me—while you explain to me—what causes the seasons for regions of the earth that have summer, fall, winter, and spring.

Model choice: tilted perpendicular

Category of responses:

- SC
  - Earth's tilt Earth's revolution around the sun Intensity/duration
- IE
- AC
- UR
- NR

Show summer in the

- Northern hemisphere. yes no
- Southern hemisphere. yes no

Comments:

From summer to winter in the
Northern hemisphere yes no
Southern hemisphere yes no
Comments:

In winter the sun is
Closer
Same
Farther
When was the last time you had formal instruction on this topic?

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