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Preservice Elementary Teachers' Conceptions of the Sun-Earth Model: A Proposal of a Teaching-Learning Sequence

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Abstract

This article addresses the teaching of astronomy (day and night, seasons) in elementary school. First, we analyzed preservice elementary teachers' understanding of astronomical concepts related to the Sun- Earth system. Taking into account the results of this analysis using a socio-constructivist approach, we designed a teaching sequence. We tested this sequence with different groups of future elementary school teachers, who showed improvement in their understanding of the Sun- Earth model.

1. INTRODUCTION

The Sun-Earth model is part of the compulsory early elementary school curriculum. However, the results of educational research show that students at all levels have serious difficulties in accounting for astronomical phenomena (e.g., Vousniadou & Brewer 1992, 1994; Schoon 1992; Lightman & Sadler 1993; Galili & Lavrik 1998). In this work, we focus on the difficulties shown by preservice elementary teachers (Atwood & Atwood 1995, 1996; Parker & Heywood 1998) because they play an important role in delivering such content. The specific aims of the study were to investigate the following questions:

1. How effective are conventional teaching approaches in facilitating learning of the Sun-Earth model? What are the major deficiencies of such approaches?
2. How might a teaching-learning sequence be designed to overcome any deficiencies?

As a starting point, we performed a detailed analysis of the historical and epistemological development of astronomy up to the Copernican model. This analysis allowed us to establish the following criteria as indicators of a solid understanding of the scientific content:

- The ability to describe the motion of the Sun in the sky throughout the day and the throughout the year. This means being aware of the existence of singular days (equinoxes and solstices) and the seasonal symmetries (e.g., for every day of summer, there is one in spring with equal features).
- Having a functional knowledge of the basic hypotheses of the scientific model. This means being able to use them to account for the day/night cycle and the seasons, and to predict the results of new observations (e.g., what happens in other latitudes).
- Understanding that observations and hypotheses of the model have different ontological statuses (e.g., it's not possible to infer a heliocentric model only by observing some experimental information).

2. EXTENDING THE INFORMATION ABOUT STUDENTS' IDEAS IN ASTRONOMY

> **Note:** In the following sections, the term *students* refers to the preservice elementary school teachers enrolled in the course, not to elementary school students.

The aim of the first phase of the study was to provide information about students' misconceptions of and difficulties understanding astronomy. By doing so, we hoped to gain insight into conditions that might help to improve students' learning. Our hypothesis was that when students graduate from high school, they lack the knowledge required to understand the Sun-Earth model. The subjects for this study were 194 preservice elementary school teachers attending a course called Didactics of Natural Science at Alicante University (Spain).

After a preliminary phase of interviews, paper and pencil questionnaires were used to probe students' views. A group of diagnostic questions was used, some based upon questions previously reported in the literature, and others that we designed. The questions tended to be in two parts. The first part (multiple-choice questions) involved students in making a prediction of some kind—for example, to compare day length or Sun altitude on different days. It was followed by an opportunity for students to explain their predictions (short essay test). The content of the questions was similar in both cases, so the essays helped us to clarify answers. The questionnaire contained 30 items. Sample questions are shown in Table 1.

Table 1. Sample Questionnaire Items

Example of Observational Question Pair

1a. Imagine that today is June 11. Approximately how many days will you have to wait for the day length to be the same?
a) 20 days
b) 180 days
c) 365 days
d) None of the above

1b. Imagine that you are in Alicante (Spain) and don't know what season it is. What observations and measurements of the motion of the Sun would you make to determine what time of year it is? Give as much detail as you can. Make drawings and show your reasoning.

Example of Theoretical Question Pair

2a. What is the main reason that days are longer in summer than in winter?
a) The Earth's orbit is not a circumference.
b) The tilt of the Earth's axis.
c) In summer, the Earth is nearer to the Sun.
d) Atmospheric phenomena.

2b. Why is the day longer in summer than in winter? Give as much detail as you can. Make drawings and show your reasoning.

The results obtained through the experimental designs have led us to the following conclusions:

- Most students were not aware of how the Sun's pathways across the sky change, and showed a distorted view of seasons (e.g., days are longer in the summer and shorter in winter, with intermediate values in spring and autumn). In addition, very few knew the existence of symmetries in the movement of the Sun. Fewer than 10% stated that day length and Sun daily maximum altitude vary symmetrically with respect to their value in the solstices.
- Most students knew the basic hypotheses of the model, but they were unable to connect them properly to observations. For example, over 80% of the students used the argument of the change of the Sun-Earth distance to explain the annual changes in day length.
- Many students showed significant confusion about the ontological status of the observations and the model. For example, 69% mixed observational and theoretical ideas when trying to describe how they could identify the season by means of observation.
- Finally, analyses of the astronomical content of the leading Spanish textbooks showed that the information displayed, both on the observational aspects and on the model, contained errors or expressions that could contribute to reinforcing students' misconceptions .

3. DESIGNING AND IMPLEMENTING A TEACHING-LEARNING SEQUENCE

Over the last decade, the science education community's interest in the design, implementation, and validation of research-based sequences for teaching science has increased sharply. For an overview, see a recent special issue of the *International Journal of Science Education* (Meheut & Psillos 2004), and for examples in astronomy education, see Gould, Willard, & Pompea 2000, and Adams, Prather, & Slater 2003. In this context, the aim of the second phase of the study was to design a teaching-learning sequence to foster a better understanding of the Sun-Earth model (see http://www.pntic.mec.es/eos/MaterialesEducativos/mem2003/astronomia/). The overall shaping of the sequence was informed by a social constructivist perspective on learning (a problem-solving approach with students engaged in a great deal of communication). In addition, an analysis of the particular learning requirements—differences between the science to be taught and typical student thinking (Leach & Scott, 2002)—was made, drawing on evidence collected in the first phase. Instructional activities were then planned to address those requirements.

We decided to take a "data-to-model" teaching approach that involved students in making observations and then developing a theoretical model consistent with those data. In the first part, the focus was on helping students to identify relevant observations, to learn to manage data from direct observations and secondary sources (e.g., from Internet databases), and to organize the new information within a coherent framework. In the second part, some conditions for students to question their models were created. Later, by means of extending their spatial representation ability, they were instructed to gradually "reinvent" the heliocentric model through a continual process of checking the fit of that model against observations.

This sequence of activities was implemented in different groups of future elementary school teachers (*N* = 132) and lasted for about 25 hours. It was taught by a university-based researcher involved in the investigation. An important aspect of the evaluation addressed the extent to which students who followed the designed teaching approach attained a richer understanding of the Sun-Earth model. It was measured not only by comparing responses with a diagnostic questions set prior to teaching, but also by using specific questions of a higher level of difficulty. The questions provided opportunities for students to use the model, and any given idea was probed through more than one question. Sample questions are shown in Table 2.

Table 2. Sample Questions for Evaluating Student Understanding

1. In an unknown place, a person has measured that the day length in summer solstice is 16 hours. 1.1. Calculate the approximate day length for winter solstice. Explain the basis for your answer. 1.2. Do you think that it is possible for daylight to last for 13 hours in this place? If so, during which season would it occur? 2. Making drawings using different points of view, use the Sun-Earth model to infer which will be the main differences in the path of the Sun, at both solstices, as observed from your city and from another place in the same meridian but farther north.

The tests showed that most students managed to understand—in the sense of being able to justify their knowledge—the Sun-Earth model. Over 80% were able to use the symmetry idea in the changes of the movement of the Sun to predict the value of local observations. A significant increase in the functional understanding of the model occurred; for example, more than 80% of students were able to use it to explain changes in day length and in Sun altitude throughout the year. To this extent, it can be claimed that the designed research-based sequence was successful in enhancing student learning.

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