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Mental models and other misconceptions in children's understanding of the earth

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ABSTRACT

This study investigated the claim (e.g., Vosniadou & Brewer's, 1992) that children have naive "mental models" of the earth and believe, for example, that the earth is flat or hollow. It tested the proposal that children appear to have these misconceptions because they find the researchers' tasks and questions to be confusing and ambiguous. Participants were 6- and 7-year-olds ($N = 127$) who were given either the mental model theorists' original drawing task or a new version in which the same instructions and questions were rephrased to minimize ambiguity and, thus, possible misinterpretation. In response to the new version, children gave substantially more indication of having scientific understanding and less of having naive mental models, suggesting that the misconceptions reported by the mental model theorists are largely methodological artifacts. There were also differences between the responses to the original version and those reported by Vosniadou and Brewer, indicating that other factors, such as cohort and cultural effects, are also likely to help explain the discrepant findings of previous research.

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Introduction

The study of children's conceptual development in the domain of observational astronomy focuses on the origins, content, and structure of children's concepts of the shape of the earth, gravity, and the day-night cycle. Vosniadou and Brewer (1992, 1994) tested the earth knowledge of 6- to 11-year-old Americans with interviews that included drawing instructions (e.g., "Can you draw a picture of the earth?"),

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“Show me where the people live”) and factual questions (e.g., “What is the shape of the earth?”, “Which way do we look to see the earth?”). In these interviews, children were also asked “generative” questions (e.g., “If you walked for many days in a straight line, where would you end up?”, “Would you ever reach the edge of the earth?”). Vosniadou and Brewer (1992) argued that generative questions have a greater potential to reveal underlying conceptual structures than do factual questions because the former require an inference from a knowledge base rather than repetition of what children have been taught.

Analysis of children’s drawings and answers has led to the claim that the majority of children have a small number of well-defined “mental models” of the earth (Vosniadou & Brewer, 1992): the “flat earth” with the people and the sky on top and an edge from which one can fall; the “hollow sphere” with the sky located inside the Northern Hemisphere and the people situated inside at the bottom of the earth; the “dual earth” consisting of a flat earth where people live and a round earth that is up in the sky; and the “spherical earth” that is round with the people and sky around it. Similar studies conducted in different cultures (e.g., Brewer, Hendrich, & Vosniadou, 1987; Diakidoy, Vosniadou, & Hawks, 1997; Hayes, Goodhew, Heit, & Gillan, 2003; Vosniadou & Brewer, 1990), and using clay model-making instead of drawings (Samarapungavan, Vosniadou, & Brewer, 1996; Vosniadou, Skopeliti, & Ikospentaki, 2004), have supported these findings and led these researchers to claim that, notwithstanding some differences in the types of mental models due to specific cultural influences, young children’s emerging concepts of the earth are largely universal.

This mental model view proposes that, before children acquire the scientific view, they form naive, theory-like mental models of the earth. These are (a) coherent, (b) constructed under the influence of flatness and support constraints that lead to the belief that the ground extends on a flat plane and all unsupported things fall, (c) reinforced by children’s observations of their local environment, and (d) used in a systematic way to explain phenomena such as whether it is possible to fall off the edge of the world (Vosniadou & Brewer, 1992, 1994; Vosniadou & Ioannides, 1998). Before any exposure to instruction, children form an “initial” mental model of a flat earth that is gradually replaced by “synthetic” models such as hollow and dual earths. Synthetic models result from the combination of children’s intuitive beliefs (e.g., the earth is flat and supported) and counterintuitive scientific facts transmitted by the culture (e.g., the earth is spherical and unsupported). Only during late childhood are synthetic models superseded by the scientific view of the spherical earth. The development of children’s knowledge of the earth from initial, through synthetic, to scientific is said to resemble the historical shifts from the ancient flat earth view, through Ptolemy’s geocentric theory, to the Copernican revolution.

Vosniadou (1994a, 1994b) described knowledge acquisition in this domain as a gradual and slow process that requires radical restructuring and theory change. Consistent with the “theory theory” (Gopnik, 2005; Wellman & Gelman, 1998) that is also applied in domains such as biology (e.g., Inagaki & Hatano, 2002; Jaakkola & Slaughter, 2003; Keil, 1989), psychology (Johnson & Wellman, 1982; Wellman & Estes, 1986), and physics (e.g., Spelke & Kinzler, 2007), children construct naive theories that enable them to explain and predict phenomena in the physical and psychological worlds. During conceptual development, they encounter new evidence that contradicts their initial conceptions and presents them with theoretical anomalies. Conceptual change, therefore, involves the gradual revision, restructuring, and replacement of these naive theories with new explanatory structures that are consistent with culturally transmitted scientific information.

A different view concerning the nature of children’s conceptions of the earth is based on studies that, instead of drawings and open questions, have used three-dimensional (3D) model selection tasks and forced-choice questions (Martin, 2006; Nobes et al., 2003; Panagiotaki, 2003; Panagiotaki, Nobes, & Banerjee, 2006b; Siegal, Butterworth, & Newcombe, 2004), picture selection tasks (Nobes, Martin, & Panagiotaki, 2005; Straatemeier, van der Maas, & Jansen, 2008), and interviews in which reference is made to a globe (Schultz, Säljö, & Wyndhamn, 2001). In these studies, children between 4 and 11 years of age were interviewed about the earth’s shape, the location of the people and sky, gravity, and the day–night cycle with questions such as “Is the earth flat or round?”, “Which of these models [sphere, disk, or hollow sphere] looks more like the earth?”, and “Some children think that people live all around the earth and other children think that people live only on top of the earth—what do you think?”

Findings from these studies suggest that young children know considerably more about the earth than the mental model theorists have proposed, and that this knowledge is fragmented rather than theory-like. According to the “fragmentation” view, young children have neither conceptions nor

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