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Astronomy Education Research Down Under

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1. Introduction

There are many problems associated with the teaching and learning of astronomy that require further investigation (Taylor & Barker 2000). Students' difficulties with visualization, mental modeling and conceptual restructuring have been reported by a number of researchers. Aspects of these important areas of research are examined in the paper. However, there has been limited focused research in the specific area of astronomy teaching (Taylor & Barker 2000; Treagust & Smith 1989). For example, the value of strategies that engage students in challenging their prior beliefs and intuitive ideas, thus enabling them to perceive patterns and grapple with frame of reference problems, and construct acceptable models of celestial phenomena, must be assessed. Such strategies might incorporate or re-enact historical discoveries (Noble 1999) thus engaging students in thinking about astronomical phenomena from an intuitive position.

2. Research into students' learning in astronomy

Research studies in astronomy indicate that students require high levels of spatial ability thinking (eg. Broadfoot 1995; Hill 1990; Vosniadou 1991a, 1991b). Ekstrom, French, Harmon & Derman (1976) defined two factors comprising spatial ability, spatial orientation and spatial visualization, as follows: spatial orientation - the ability to perceive spatial patterns or to maintain orientation with respect to objects in space (p. 149); and spatial visualization - the ability to manipulate or transform the image of spatial patterns into other arrangements (p. 173). Research into these aspects of spatial thinking, as well as mental modeling, are examined briefly in the following sections.

Spatial orientation: Astronomy frequently requires students to imagine objects from other viewpoints (Rock, Wheeler & Tudor, 1989), which demands a shift in perspective or change in the student's frame of reference (Finegold & Pundak 1990). Object-centered and observer centered viewpoints (Marr & Nishihara 1978; Marr 1982), an egocentric viewpoint (Steiger & Yuille 1983), and encoded landmarks (Evans, Marrero & Butler 1981), are descriptors of some of the ways that frames of reference can be established. Orientation frameworks may be constructed on the basis of a combination of at least four factors: gravitational direction, viewing direction, bodily direction, and environmental features (Broadfoot 1995). Orientation bound descriptions are essential for understanding the relative positions and motions of celestial objects. Broadfoot (1995) and

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Feteris & Hutton (2000) demonstrated that individuals may initially comprehend the relative positions of objects such as constellations in space without a comprehensive orientational or orthogonal framework but fine tune the exact location of objects in space as an outcome of increasing field experience

Spatial visualization and transformations: An object-centered viewpoint of, for example, the Sun-Earth-Moon system, may necessitate considerable mental transformation by the observer from his/her viewpoint, which may result in conflict of object-centered (heliocentric) views with observer-centered (egocentric) views. Lucas & Cohen (1999) described the difficulties faced by students when relating textbook diagrams about seasons, which were mostly heliocentric, to activities of a geocentric nature.

Students often deal with orbital and rotational movements of celestial objects in the study of astronomy. Shepard & Cooper (1982) reported that orientation of mental images of three-dimensions often required transformations that increased in difficulty as the angle of rotation of an object from the original position increased. They noted that it was difficult for students to recognize the similarities between two dimensional drawings of the same three-dimensional situations, which may apply to problems where students attempt to interpret two-dimensional representations of the changing phases of the moon.

Mental models: Vosniadou (1989, 1991a) identified three kinds of mental models for explaining observed phenomena that provide insights into the constructs of students' knowledge bases. These are categorized as intuitive, scientific and synthetic models. The intuitive model, based on observational experiences of the natural world, requires little modification for accommodation of first-hand observations. Scientific models are in accord with current scientific views. Synthetic models show a combination of intuitive and scientific views and represent some kind of misrepresentation of scientific information. Vosniadou (1991a) concluded that a mental model of a spherical earth is a prerequisite to understanding the scientific explanation of the day/night cycle as is also an understanding of axis. The two concepts, spherical earth and axis, are examples of interdependence among concepts which are very important in understanding astronomy.

Glynn, Yeany & Britton (1991) discussed conceptual development in terms of intuitive understandings of the world. A flat earth, stationary and central to the universe, effects of gravity, the sun and moon moving up and down or east to west, and the stars being small are just some of the intuitive models possessed by many students (Vosniadou 1991a). Taylor & Barker (2000) investigated how learners constructed mental models when studying the Sun-Earth-Moon system and recommended that mental-model building should form the basis of astronomy education, a conclusion supported by Dunlop (2000) who studied students' learning through engagement in planetarium sessions.

3. Research into teaching and learning strategies in astronomy

The design of curricula for the teaching of astronomy should present concepts in an appropriate sequence and students should be provided with opportunities to examine their personal beliefs and explain their understandings of relevant concepts (Vosniadou 1991b). In addition, a number of researchers have suggested

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that the inclusion of activities that develop and enhance student spatial thinking abilities is highly desirable in the development of learning materials and teaching strategies for astronomy (e.g., Eylon & Linn 1988; McCubbin & Embeywa 1987). These activities should be based on direct observation (Lucas & Cohen 1999), and spatial training exercises should be included to develop student orientation frameworks and to enhance spatial visualization and transformation of dynamic celestial phenomena (Broadfoot 1995). Personal or collective investigations by students may be reinforced with a number of observer-centered, concrete three-dimensional models (Bishop 1990; Broadfoot 1995; Dunlop 2000; Domenech & Casasus 1991; MacIntyre 2003). These models need to be pertinent and make interactions transparent to students (Hill 1990), and students also require time to explore ideas when using the models to develop the complex spatial concepts in astronomy (Bishop 1988; Sadler & Luzader 1990). Quite often verification of astronomical concepts is not possible from direct observations (Hill 1990), for example, the sphericity of the earth or the heliocentric nature of the solar system.

Active involvement by students in modeling has been shown to be useful in astronomy teaching (Sadler & Luzader 1990). Students can model lunar and planetary motion, and star positions in conjunction with real sky activities and events. Investigating day and night, and the phases of the moon, through role-play would represent a possible starting point for the use of modeling as a way of examining and explaining celestial concepts and natural phenomena that are easily observable. Sweitzer (1990) has advocated the use of pictorial models, and Mazzolini & Halls (2000) have engaged students in computer modeling of celestial phenomena.

Other strategies for teaching astronomy include the use of analogies and the identification of similarities in students' concepts or beliefs (Vosniadou & Ortony 1989; Smith 1989), and an approach based on the historical development of knowledge in the field of astronomy (Glynn et al. 1991).

4. Recommendations for research

The first section of this paper drew attention to the difficulties learners face when grappling with the complexities of observing astronomical phenomena and when seeking to explain their observations. The second section of the paper examined briefly approaches and strategies that may be used to enhance the teaching and learning of astronomy. Based on this background of research findings, the paper concludes with exemplars of possible further research investigations that should be conducted in order to evaluate the effectiveness of these approaches and strategies in overcoming the difficulties experienced by students. It is only through approaches that take into account the analysis of the problems inherent in the learning of astronomy that gains will be made in this area. Our exemplars of possible research follow:

Learning and teaching: What thinking processes, with respect to orientation frameworks, do students use when confronting celestial motion problems? How do students interpret information from given data and restructure the information into different viewpoints both verbally and diagrammatically? What concepts are prerequisites and interdependent in astronomy learnings?

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Teacher training: What is the exact nature of, and what factors affect, the designed and implemented curricula in astronomy in our tertiary institutions? Do these curricula produce teachers who are competent in teaching astronomy?

Primary and secondary schools: What is the exact nature of, and what factors affect, the designed and implemented curricula in astronomy in our primary and secondary schools? Do these curricula engage students in challenging and constructing their own knowledge and understanding of astronomy?

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