TEACHING EARTH-SUN-MOON CONCEPTS: A SOUTH AFRICAN PERSPECTIVE

M Stanton

School of Physics, University of the Witwatersrand, Johannesburg, South Africa

The new curriculum in South African schools has moved the teaching of the solar system and related concepts from geography to the Natural Science Learning Area. This is problematic for many science teachers: there are learner difficulties that under-qualified teachers may not appreciate, and errors perpetuate. Traditional rote delivery seldom identifies these problems. Our premise is that these difficulties arise from the complex concepts that require a visualization of the 3-D spatial relationships between the Earth, sun and moon and the changing configurations as these bodies revolve and rotate, and that these difficulties might be attributed to poor visual literacy skills and/or a lack of spatial ability skills.

GENERAL INTRODUCTION

The advent of the post-apartheid democratic government in South Africa in 1994 brought about major changes in the secondary school system. These changes were three-fold:

<u>A change in the underpinning philosophy</u>. There was an urgent need to move away from a purely Western oriented viewpoint of the aims of education. The incumbent ruling party (1948-1994) had espoused a Calvinistic oriented Christian National Education (CNE). The new constitution now required that education should emphasize, inter alia, social transformation, human rights, inclusivity, environmental and social justice, and a *valuing of indigenous knowledge systems* (DoE, 2003:1).

<u>A change in the method of delivery</u>. The existing method was formal and didactic, and rote-learning had become the norm. The new dispensation has moved to Outcomes Based Education (OBE), which emphasizes, *inter alia*, high knowledge and high skills; integration and applied competence; articulation and portability; credibility, quality and efficiency (DoE, 2003:1). A higher degree of self-responsibility is placed on students; teachers should act as mediators of learning rather than as purveyors of knowledge.

<u>A change in the curriculum</u>. – Curricula in 1994 still had many of the semblances of the traditional, classical English system. The call was now for curricula that were modern, relevant, and utilitarian for higher learning and future employment.

This paper is primarily concerned with astronomy education in the natural sciences curriculum.

Organization of the South African Education System: Grades 1 to 9 encompass General Education and Training (GET), while Grades 10 to 12 constitutes Further Education and Training (FET). By 2008, an FET Certificate with appropriate pass levels will be required for university entrance. In the GET, physical science and the life sciences are combined in the Natural Science Learning Area, while in the FET, there are separate physical and life sciences fields of study.

TEACHING OF THE SOLAR SYSTEM

In the GET, one of the strands is “Earth and Beyond”, and it is here that the solar system and related issues are taught in Grades 8 and 9. The study of the solar system was formerly taught in Geography. **And hereby is a major problem**. Geography teachers were explicitly trained to teach the topic, BUT natural science teachers are generally trained in physics & chemistry, or in botany & zoology. Few natural science teachers have geography in their teacher training profile, and so this topic – the solar system – is now being taught by teachers who lack much of the basic content knowledge. In a study at the University of KwaZulu Natal (UKZN), Govender & Naidoo (2006) have found that student teachers' specific conceptual and content knowledge of astronomy needs to be strengthened, particularly for those students coming from previously disadvantaged and non-Western communities. In a recent teachers' workshop in Johannesburg, many participants had little knowledge of even the most basic aspects of the solar system.

At the FET level, the recently published new curriculum contains some ambitious inclusions, for instance: red shifts in the universe (evidence for the expanding universe), gravitational lenses, fission and fusion and their consequences; nucleosynthesis. In the Learning Outcome 3 (Nature of Science and its Relationship to Technology, Society and the Environment) there are several allusions to astronomy and cosmology. Here the very small number of teachers with higher courses in physics in their teacher training profile suggests problems in implementing such items.

The inclusion of astronomy and cosmology does satisfy some of the requirements alluded to in the introduction: *inter alia*, indigenous knowledge and relevance. The Oxford English Dictionary describes cosmology as both the theory of the universe as an ordered whole, and of the general laws that govern it, and (philosophically) as that part of metaphysics which deals with the ideas of the world as a totality of all phenomena in space and time. Cosmology is thus a branch of both physics and metaphysics. In the South African context, this opens up discussion of African cosmologies and traditional African thought. Such discussion is helpful in promoting appreciation of Indigenous Knowledge Systems (IKS) amongst students. Africa indeed has a rich astronomical and cosmological heritage - ancient cultures made remarkably accurate observations, and built up a heritage of myths and legends, relayed in sacred ceremonies and rituals, and immortalized in art. Again studies at UKZN (Govinden & Govender, 2006) have looked at trainee teachers' interaction between Western cosmology and personal religious beliefs and indigenous knowledge: the stronger the commitment to the latter, the more difficulty is encountered in teaching astronomy and cosmology. On the other hand, Govender (2006), in a study of Zulu and Basotho students, has shown that indigenous views on astronomical observations can be used as a meaningful springboard in teaching Western cosmology.

Much of the initial mapping of the Southern milky-way took place in South Africa - undertaken in Cape Town by Sir John Herschel between 1834 and 1838. South Africa continues to make contributions to the deeper understanding of the universe through the newly constructed **Southern African Large Telescope (SALT)** at Sutherland, and the shortly-to-be-constructed **Karoo Array Telescope (KAT)** in the Northern Cape Province. Furthermore international discussions are under way to build a **Square Kilometre Array (SKA)** radio telescope facility in South Africa.

It is therefore relevant and appropriate to consider inclusion of astronomy and cosmology into our secondary school curricula, BUT there is a serious problem relating to the ability of our teachers to handle such topics. In solar system studies, research literature (e.g. Trumper, 2001; Trundle, 2002) shows that students experience many difficulties in understanding concepts related to the relative motions and configurations of the Earth, sun and moon: *i.e.* the causes of day and night, the seasons, and solar and lunar eclipses.

Accordingly we have embarked recently in studies relating to students' abilities to understand these topics, and teacher's abilities to teach them (Mosoloane, 2005; Misser, 2006; Sanders, Mosoloane & Stanton, 2006). Research to date has been conducted in the urban areas in and around Johannesburg.

Mosoloane (2004) studied Grade 10 students' conceptions about day and night and the seasons, after instruction in these topics. The study was conducted in underprivileged and under-resourced "township" schools, where teachers are often un- or under-qualified. An open-ended diagnostic questionnaire was used. Results showed that a majority of students lacked scientifically acceptable conceptions of day and night, and the seasons, *e.g.* they did not understand the combined rotation of the earth about its axis, and the revolution of the Earth about the sun. Results also showed that students could not properly interpret diagrams, or effectively use diagrams to clarify answers. They lack scientifically acceptable conceptions despite detailed explanations given in their textbooks, implying that the textbooks were not effectively used during instruction, or that the material is simply not understood. At the same time it was however found that some teachers seemed inadequately qualified to teach the topics, and there was little evidence of any use of 3-D models or explanations.

Misser (2005) has studied Grade 9 students' understanding of eclipses and phases of the moon in three better resourced schools. An open-ended written questionnaire was employed to obtain evidence of knowledge and understanding of phases of the moon, lunar and solar eclipses, and any personal beliefs about eclipses. A number of the items required students to draw diagrams. It was found that students had great difficulty in attempting to draw an essentially 3-D phenomenon onto a 2-D page. They had serious difficulties with regard to the orientation of the sun, moon and Earth in both types of eclipse. They were unable to explain which phases of the moon occurred during solar and lunar eclipses, and indeed were confused between the two types of eclipse. In general students were unable to describe and explain celestial body movements, or to visualize spatial phenomena.

STUDENT DIFFICULTIES

Both studies have revealed that students can provide rote-learned responses (for example, they can tell that day and night are caused by the rotation of the earth on its axis), but have great difficulty in explaining why and how this actually happens. A further problem is that, because these phenomena are "everyday" occurrences, many children arrive in the classroom with pre-existing explanations either derived from their cultural beliefs, or from ideas that they developed on their own. These ideas (termed variously as naïve ideas, misconceptions, alternative conceptions or frameworks, . . .) interfere with successful teaching and learning.

However there are other possible sources of difficulty posited in the literature, and which are a fruitful source for further investigation. These are complex concepts which require students to visualize 3-D spatial relationships between the Earth, sun and moon, and the continually changing configurations of the three bodies as they "revolve" and "rotate", two "r" words that students have difficulties in discriminating between. The investigations of Mosoloane (2004) and Misser (2005) also showed that some teachers themselves had erroneous or confusing ideas, which they seemed to be transferring to learners. One such notion is that lunar phases are due to the shadow of the earth! Furthermore traditional teachers who simply "explain the facts" do not provide students with the chance to explore ideas for themselves. Even the use of 3-D models is not always effective. A big difficulty with the solar system is the question of scale: use of (say) a soccer ball, tennis ball and pig-pong ball on a table is a massive distortion of scale which may cause more problems than it resolves: the tilt of the earth's axis is not apparent, as also the problem that the orbit of the moon is at 5° to ecliptic, resulting in students not understanding why lunar eclipses do not occur monthly. Diagrams in textbooks are 2-D, and attempts to indicate the 3-D nature of the problem generally inadequate, or in extreme instances wrong, as we have founded in a number of local textbooks.

Research has also shown that viewers cannot always interpret diagrams (and even models) in the way intended by the authors, artists or teachers. Assuming even that the viewers are interested and make the effort to interpret the diagrams, this problem could be caused by (i) a lack of visual literacy skills intended as an aid to learning, or (ii) a lack of spatial ability skills to help them visualize and interpret the 3-D configurations and changes being depicted.

CURRENT RESEARCH

Accordingly our current research looks at

The efficacy and limitations of textbook diagrams: We are scrutinizing the diagrams used in current and recent South African school texts (and others). We test against certain "standard" criteria in the literature, but more importantly workshop and interview teachers on how and when they use the diagrams, how they interpret the diagrams, and how they think students might view the diagrams (Sanders, Mosoloane & Stanton, 2006). The plan-view of the phases of the moon often shown in text books causes some confusion between phases of the moon and lunar eclipses. Tests on students will follow.

The spatial abilities needed to interpret diagrams and understand astronomy concepts. We will be using standard tests developed by Ekstrom *et al.* (1976) to test students for spatial perception, spatial orientation and spatial visualization. These tests involve such items as: rotations of 2-D figures in a plane, and cubes in multiple planes; finding hidden figures; and paper folding exercises. The results of these tests will be correlated against test items on the Earth-sun-moon orientation which particularly involve such skills. We hypothesize that poor spatial abilities are a root cause of the difficulties students have with solar system concepts, but this needs to be tested.

The use of models. We have developed two physical models of the Earth-moon system (Sanders, Mosoloane & Stanton, 2006). One is a robust large model, the main feature of which is the tilt of the plane of the moon's orbit to the ecliptic. As our "moon", a small polystyrene sphere, moves around our "earth", a larger polystyrene sphere, it is clear that the moon is sometimes above the ecliptic, sometimes below, and only twice per lunar month on the ecliptic, but then seldom such that the sun, moon and earth will be co-linear for an eclipse. Our "moon" always presents the same face to the earth, but our "earth" rotates. As our "moon" moves relative to our light source (the "sun"), in a darkened room, the phases of the moon can be traced. We have also developed a small inexpensive model that can be made from materials that are easily accessible. The efficacy of the models is currently being tested with teachers.

References

DoE (Department of Education). (2003). National Curriculum Statement Grades 10-12 (General) – Physical Sciences. Pretoria: Government Printer.

Ekstrom, R., French, H., Harman, H. & Derman, D. (1976). Manual for kit of factor referenced cognitive tests. Educational Testing Service. Princeton, New Jersey.

Govender, N. & Naidoo, K.K. (2006). Science education honours teachers' views, planning and classroom implementation of Nature of Science in the physical science curriculum. *Proc 3rd Conf. of the South African Association of Science & Technology Educators (SAASTE)* (pp.13-25), Durban RSA.

Govender, N. (2006). Southern African students' – Zulu and Basotho- cultural and indigenous experiences of astronomy. *Proc 3rd Conf. SAASTE* (pp.31-38), Durban RSA.

Govinden, H & Govender, N. (2006) Pre-service physical science student-teachers' conceptions of science, religion and indigenous knowledge with reference to the teaching of cosmology at the FET level. *Proc 3rd Conf. SAASTE* (pp.26-30), Durban RSA.

Misser, P.D. (2006). An investigation into Grade 9 learners' understanding about phases of the moon and eclipses. Unpublished MSc Research Report, University of the Witwatersrand, Johannesburg, RSA.

Mosoloane, R. (2005). Learners' conceptions about astronomical concepts related to the sun and the Earth. Unpublished MSc Research Report, University of the Witwatersrand, Johannesburg, RSA.

Sanders, M., Mosoloane, R. & Stanton, M. (2006). Issues relating to the use of support materials in the teaching and learning of concepts associated with the Earth-sun-moon configuration. *Proc 3rd Conf. SAASTE* (pp.122-138), Durban RSA.

Trumper, R. (2001). A cross-age study of senior high school learners conceptions of basic astronomy concepts. *Research in Science and Technology Education, 19(1),* 97-107.

Trundle, C.K. (2002). Pre-service elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching, 39(7),* 633-658.