ESERA 2021
Fostering scientific citizenship in an uncertain world
30 Aug - 3 Sep 2021
Organised by
University of Minho, Braga, Portugal

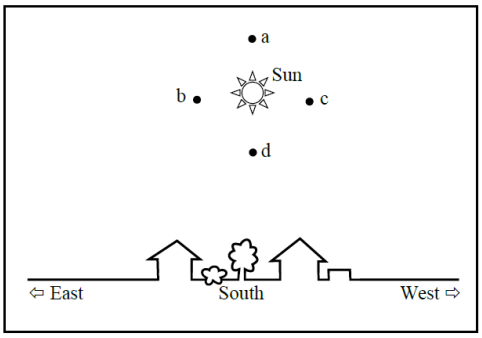
IDENTIFYING STUDENTS' MENTAL MODELS OF THE APPARENT MOTION OF THE SUN AND STARS.

Abstract. *To study to what extent students have insight in the Apparent Motion of the Sun and Stars, we have designed the AMoSS test instrument with 12 multiple choice questions, which focus on distinctions between different aspects of the apparent motion of the Sun and stars. We administered the AMoSS test to students of the fifth year (16-17 years old) of 6 Belgian secondary schools (N=410) during a science lesson in school and asked them to explain their choices. The analysis of the answers on the multiple-choice questions and the written explanations, reveal that, despite instruction, most students only demonstrate a rudimentary understanding of the apparent motion of the Sun and stars for different locations of the observer and different times during the year. On top of that, there is a clear distinction between the replies for the stars and the Sun. Thanks to the classification system that we have developed to categorize the written explanations, we are able to identify different mental models that students have about the apparent motion of the Sun and stars.*

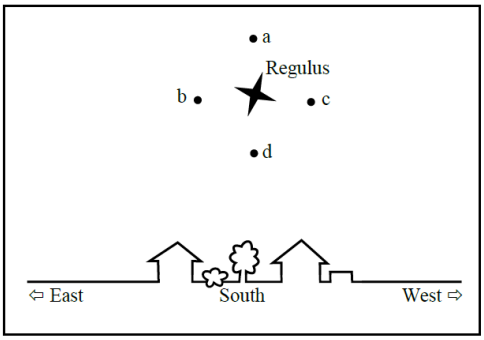
Keywords: Mental models – Misconceptions – Secondary school

1. INTRODUCTION AND PROBLEM STATEMENT

Although the apparent motion of the Sun and stars is part of our daily life, research reveals that many students have alternative conceptions about this phenomenon (Slater et al., 2015; Plummer, 2009; Vosniadou & Brewer, 1994; Trumper 2001). However, only little is known on students' understanding of similarities and differences between the apparent motion of the Sun and stars. This study focusses on these differences and similarities. We therefore designed a framework to disentangle different factors that influence the apparent motion and to compare these different aspects for the Sun and stars in relation to the time of the day, time of the year and the observer's latitude. For each factor we designed test items, also inspired by literature. This resulted in the AMoSS test (Author, 2020) with 12 multiple choice questions: 6 questions about the Sun and 6 parallel questions about the stars. Fig. 1 shows the first two questions of the AMoSS test as an example of two parallel items.



Question (a): On March 21st, an observer in Brussels sees the Sun in the south high above the horizon as shown in the figure. Where does this observer see the Sun one hour later?



Question (b): On March 21st, an observer in Brussels sees the star Regulus in the south high above the horizon as shown in the figure. Where will this observer see Regulus one hour later?

Fig. 1 Two corresponding questions: (a) The apparent motion of the Sun. (b) The apparent motion of stars.

We administered the test to 410 high school students (16-17 years old) during a science class. The mean score for all participants on all questions was M = 45%, SD = 18%. On average the six Sun questions (M = 55%, SD= 24%) are answered more correctly than the six star questions (M = 36%, SD = 21%). We also asked the students to explain their answers in order to get insight in the mental models students use. Due to time constraints, the students wrote explanations for 6 out of 12 questions in random selections. In this paper, we report on the classification system we have designed to categorize these written explanations and on the mental models we have identified.

2. CLASSIFICATION SYSTEM OF THE WRITTEN EXPLANATIONS

Literature indicates that specific instruction is needed to make students understand the basics of the celestial motion of the Sun, Moon and stars. This dedicated instruction should consider the motion of celestial objects from both an Earth-based and an allocentric frame of reference (Plummer et al., 2011; Testa et al.,2015; Sneider et al., 2011). Based on this idea we have classified the written explanations into four groups:

1. *Statement (S):* the explanation is based on an observation from the point of view of an observer on Earth or on something the student knows;
2. *Model (M):* the explanation shows at least one element of an allocentric point of view;
3. *Incomprehensible (Z):* it's not clear what the student means;
4. *No explanation (X):* the student has not written an explanation.

For each written explanation we also indicated whether the written explanation was correct (C) or false (F). Table I shows some examples of students' answers, concerning the questions in Fig. 1.

Table I: Example of the classification of students' written explanations of the first two questions of the AMoSS test (see Fig. 1).

Statement (S)	Model (M)
"The Sun rises in the east, culminates in the south and sets in the west." (SC). *"Stars move from the west to the east."* (SF).	*"Since the Earth rotates about its axis from the west to the east, the Sun moves in the sky from the east to the west."* (MC) *"The Earth rotates but the star doesn't move in the sky."* (MF)

The categorization of students' written explanations reveals that for the questions about the Sun students tend to use a statement as an explanation of their answer of the multiple-choice question more often than for the stars questions. A paired-samples t-test was conducted to compare the number of explanations classified as statement (S) between the six Sun and the six star questions. There was a significant difference in the scores for the Sun (M = 1.70, SD = 0.91) and the star (M = 0.98, SD = 0.82) questions, $t(409)=14.7$, $p < 0.001$.

3. STUDENTS' MENTAL MODELS

For a more detailed understanding of how students explain the phenomena of apparent motion, we try to identify their underlying mental models. Although there is no agreement about the exact definition of the mental model, in general, the term refers to the internal representations that people form of the outside world through their interaction with it. Bao (Bao, 1999) put forward his definition of mental models by considering other descriptions in the literature. According to him, mental models are *"productive mental structures that can be applied to a variety of different physical contexts to generate explanatory results"* (p. 13). Corpuz

and Rebello (Corpuz & Rebello, 2005, 2011) defined a mental model as *"students' way of understanding a certain physical phenomenon,"* which can also be unseen physical phenomena. Mental models may contain contradictory elements and are generally different from scientific models, which are accepted as valid if they are coherent, stable, and experimentally validated.

For both the model-based and the statement-based student explanations, we built a categorization scheme bottom up from the data. This resulted in a coherent classification system which we checked for interrater reliability with satisfactory results (overall Cohen's kappa = 0.75). Based on the classification of all student answers and by studying answer patterns over different questions, we identified specific mental models students use to explain different aspects of the apparent motion of the Sun and stars.

4. CONCLUSION

Administering the Apparent Motion of the Sun and stars test (AMoSS) with a group of Belgian students of the fifth year (16/17 year olds) of secondary education (N=410), allowed for identifying students' mental models they use while explaining their answers.

In the presentation, the categorisation system of the written explanations and the identification of student mental models about the apparent motion of the Sun and stars, will be discussed in detail.

5. ACKNOWLEDGMENTS

The work was co-funded by the Erasmus+ programme of the European Union (2020-1-IT02-KA201-079528).

REFERENCES

Bao, L. (1999). Dynamics of Student Modeling: A Theory, Algorithms, and Application to Quantum Mechanics. *Phd thesis.*

Corpuz, E. D., & Rebello, N. S. (2011). Investigating Students' Mental Models and Knowledge Construction of Microscopic Friction. I. Implications for Curriculum Design and Development. *Physical Review Special Topics - Physics Education Research, 7*, 2.

Corpuz, E. D., & Rebello, N. S. (2005). Introductory College Physics Students' Explanations of Friction and Related Phenomena at the Microscopic Level. *AIP Conference Proceedings 790 (September)*, 153–56.

Plummer, J.D. (2009). A Cross-Age Study of Children's Knowledge of Apparent Celestial Motion. *International Journal of Science Education 31*, 1571–1605.

Plummer, J. D., Wasko, K.D., & Slagle, C. (2011). Children Learning to Explain Daily Celestial Motion : Understanding Astronomy across Moving Frames of Reference. *International Journal of Science Education 33*, 1963.

Slater, S. J, Shleigh, S. P., & Stork, D. J. (2015). Analysis of Individual Test of Astronomy STandards (TOAST) Item Responses. *Journal of Astronomy & Earth Sciences Education 2*, 89–108.

Sneider, C., Bar, V., & Kavanagh, C. (2011). Learning about Seasons: A Guide for Teachers and Curriculum Developers. *Astronomy Education Review 10*, 010103.

Testa, I., Galano, S., Leccia, S., & Puddu, E. (2015). Development and Validation of a Learning Progression for Change of Seasons, Solar and Lunar Eclipses, and Moon Phases. *Physical Review Special Topics - Physics Education Research 11*, 020102.

Trumper, R. (2001). A Cross-Age Study of Junior High School Students' Conceptions of Basic Astronomy Concepts. *International Journal of Science Education 23*, 1111–23.

Vosniadou, S., & Brewer, W. F. (1994). Mental Models of the Day/Night Cycle. *Cognitive Science 18*: 123–83.