

# THE EARTH IS FLAT! EXPLORING THE MENTAL MODELS OF THE SOLAR SYSTEM IN THE FOUNDATION PHASE

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**ABSTRACT-** This paper aims at describing the changes in the mental models that foundation phase learners construct about the relationships between the Earth, the Sun and the Moon. A series of clinical interviews were conducted with Foundation phase learners at a primary school in Soweto, Johannesburg, to elicit their thinking in relation to the shape, colour and relative positions of the Earth, the Sun and the Moon. The participants in this study consisted of 10 grade R and 10 grade three learners. Learners constructed their representations of the Earth, the Sun and the Moon using clay. From this, their intuitive ideas about colours and shapes of these objects became evident. The question this research asks is: "How do learners' concepts of the relationships between the Earth, Moon, and Sun change throughout the foundation phase?" Data was collected through interviews and video recordings and was analyzed using open coding. The findings revealed that there is a marked change between the flat Earth models that are prevalent with the grade R sample and the spherical depictions made by the grade 3 learners. The findings further show that despite the changes in representations of the shape of the Earth, most learners still hold a geocentric model of the solar system. The authors recommend that foundation phase teachers use the protocol that was developed for these interviews as a means to establish the intuitive theories that children hold before attempting to teach content relating to weather, seasons, day/night cycles and the solar system. This is necessary as the learning of these concepts are dependent on their understanding of the relationships between the Earth, the Sun and the Moon. By determining the prior knowledge of learners, teachers can effectively inform their teaching strategies and adapt to the competencies of these learners. In so doing, it ensures that learners reach the normative understanding of these natural phenomena. The authors argue that the limited time spent on teaching concepts relating to the solar system leads to minimal change in the concepts that these learners hold. This impacts on a learners' journey to reaching a normative understanding of such concepts.

**Keywords:** Conceptual Change, Science Education in the Foundation Phase, Astronomy Content taught in the Foundation Phase.

## 1. INTRODUCTION

It took the scientific community more than 2000 years to agree on the heliocentric notion of the earth as a sphere that spins on its axis and revolves around the sun (Brewer, 1989). This could be attributed to some societies in history holding the geocentric notion of the earth being flat, motionless, the center of the solar system and the sun revolving around it (Kuhn, 1957; Lambert, 1975; Toulmin & Goodfield, 1961). As such, the debates around ideas about the size, shape and positions of the Earth, Sun and Moon has continued for many centuries. A number of studies (e.g. Baxter, 1989; Nussbaum, 1979, 1985; Sharp, 1995; Vosniadou & Brewer, 1990) focusing on young children's notions of the shape of the earth and its position in space relative to that of the sun and the moon have been developed. Blown (2013) argues that learners' concepts of celestial bodies are influenced by their concept of the Earth, and that children who hold that the Earth is a spherical planet with a single Moon, both being members of the Solar System with the Sun as the main body, have close to a scientific understanding of 'the Earth'. This view infers that learners' normative concepts of the Earth, Sun and Moon (E-M-S) model are influenced by their ideas of what the earth looks like.

In South Africa there has been little research done on how learners in the early grades conceptualize scientific ideas. Henning (2012) emphasized that we know far too little about the developing mind,

how children form science concepts and how they learn from the curriculum. The fact that the research community in South Africa has not produced enough evidence based research on how early grade children learn science is a source of concern (Henning, 2012). The lack of research thereof brings us to an interesting enquiry, and also the importance of how our learners' concepts about the natural world, and in particular how they understand the relationship of the Earth, Sun and Moon develop. This evokes the research question: How do learners' concepts of the relationships between the Earth, Moon, and Sun change throughout the foundation phase? A gap arises in the South African literature due to the limited enquiry in South African foundation phase learners' emergent scientific concepts and how these concepts change.

Hence the aim of this study is to determine how learners' concepts of the E-M-S model change throughout the foundation phase in South Africa. Although this is not a longitudinal study, we are concerned with interrogating and comparing the current mental models of both grade R and grade 3 learners. Through this we anticipate to see if there is any change between grade R and 3 learners' concepts of the Earth, Moon and Sun. We argue that from grade R to 3 there is a qualitative change in learners' concepts of the E-M-S model despite the minimal content that is included as part of the national foundation phase curriculum. However, due to the little classroom time invested on this topic, the change that is present does not develop from "naïve" to normative as described by diSessa (2006). Piaget stated that the teaching of astronomy concepts to young children too soon would be useless as they could not possibly understand the intricacies of such an abstraction. Likewise, Mali and Howe (1979) bring to our attention that the problem with teaching concepts such as the E-M-S models in the first three grades is "that the child will be told and accept the new notions of earth, sun and moon without understanding the meaning of the evidence". These arguments are worthy of citing because they attempt to bring our attention to possible limitations in terms of identifying change in the E-M-S models of young learners.

## **2. Exploring the Earth-Sun-Moon mental model as part of the Life Skills Curriculum**

### **2.1. What learners should know: interrogating time allocation in the Life Skills Curriculum**

Literature about the instructional time for scientific concepts suggests that the more time spent teaching these concepts, the better learners perform and develop more scientific theories (National Center for Educational Statistics, 2005). A 2005 study conducted by the National Center for Education Statistics in the United States examined the relationship between the time grade 4 teachers invested in science teaching and the performance of their learners. They found that learners receiving at least 2-2.9 hours of science instruction per week met or exceeded the national average Scale Score (152/300) and those receiving less science instruction scored below the average (National Center for Educational Statistics, 2005). This provides evidence that time allocation and performances in science are directly proportional. As such, for the benefit of this study we will look into the sub area of 'Beginning knowledge' as described in the foundation phase curriculum, what it entails and also the time allocated per week. I believe that in our quest to establishing what foundation phase learners know with regard to the E-M-S model it is important to note the time allocated to the teaching of this and related concepts during the early schooling years. This will assist us in identifying if the time allocated to learning about the E-M-S model is sufficient or not. We see from the curriculum document that in grade R learners do not learn about Astronomy in any of the four terms. Topics like the weather, seasons and the days are however covered. In order for learners to truly grasp topics about the weather and seasons, it is important for them to also understand basic concepts of the E-M-S model. These basic concepts underpin the scientific understanding of the weather, day/night cycle and the seasons. It is only in grade 1, during the fourth term, that the topic "The sky at night" is covered for only 4 hours. Here, learners are expected to learn the following concepts "Changing from day to night, What the night sky looks like, What the moon looks like, When we can see the moon, How the moon

seems to change shape, A star burns like the sun (The sun is a star)" (Department of Basic Education, 2011).

In grade two the topic is not covered at all and only in the third term of grade three do learners interact with the topic "space" which is to be covered for six hours in that term. According to the curriculum the themes to be covered in this topic are: "Earth from space, what it looks like (land, sea, and clouds), Stars and planets, what they are, Names of the planets, Telescopes, Space travel, Satellites and information we get."

## **2.2. How children acquire their concepts and how these concepts change**

Children, like scientists have an unquenchable thirst for understanding how the world operates. The "theory theory" of conceptual development, suggests that starting in infancy, continuing through life, and canalised in scientific inquiry, many aspects of human learning can be best explained in terms of theory formation and theory change (Gopnik, 2007). It is essentially a theory about how children learn and how what is learned changes. It asserts that "children's naïve theories should be subject to confirmation, revision and refutation and that children should be able to make inferences based on observation, experimentation and combinations of the two" (Gopnik, 2007, p. 68). The implication, in reference to this theory, implies that children are engaged in these processes of confirmation and refutation, like little scientists. Thus, we can infer that their causal reasoning plays an important role in concept acquisition and development. A causal theory as described by Gopnik and Meltzoff (1997), must enhance novel predictions and interventions. In addition, it must account for a wide range of data, enable inferences about the existence of unobserved and even unobservable causes, and change flexibly with evidence. In this study we are interested in presenting aspects of causation that are aligned to children's intuitive ideas and judgments.

Like scientific theories, intuitive ideas are composed of a combination of causal laws and ontology of concepts that determine how various concepts interrelate. Carey (2009) postulates that people have intuitive theories of different disciplines, such as astrology, psychology, physics and biology, which are in some way analogous to scientific theories. While the concepts and laws in a scientific theory are explicitly defined and known to the scientists in their respective fields, the operation of intuitive theories may be implicit and thus potentially unknown to their user.

## **2.3. Research on the Position, Shape and Size of the Earth, Sun and Moon**

Spearheading research on the E-M-S models of young learners has been the acclaimed work of Vosniadou (1991). She interviewed 60 children in the USA of grades 1, 3 and 5 (20 learners per grade); and 90 children in Greece with preschoolers (30), grades 3 (30) and 6 (30). In order to observe the changes in ideas of the relative position and sizes of the Earth, Sun and Moon, Vosniadou (1991) asked learners to "Think about the Earth, the Sun, the Moon, and the Stars. Which is the biggest: the Earth, the Sun, the Moon, or the Stars?" Her work revealed interesting changes in the concepts of learners. The total amount of learners who believed that the Earth was biggest reduced as learners became older. The study showed that 75% of the grade 1 learners, 27% of the grade 3 learners and 12.5% of the grade 5 learners believed Earth was the biggest. However, in contrast the number of learners who believed that the Sun was biggest escalated with age as 19% of the grade 1, 53% of the grade 3 and 50% of grade 5 children believing that the sun is the largest.

An example of the theoretical and methodical framework we aim to adopt is contained in Sharp (1996). In his paper, Sharp collected data from interviews with 42 learners aged 12 with the aim to explore young learners' prior ideas of the shape of the moon and sun. Firstly, the results on the Sun were categorized into seven groups: (1) round, roundish, ragged (n30); (2) sphere (n5); (3) like a ball

(n1); (4) like the Earth (n4); (5) circle (n1); (6) oblong (n1) and (n7) unsure (3). Secondly with reference to the moon Sharp (1995) conducted interviews with 20 learners from England aged 6 to The results of this study were grouped into 9 categories: (1) sphere (n4); (2) big circle (n4); (3) like a banana (n3); (4) ball (n2); (5) 'D' shape but thinner (n1); (6) sometimes round (n1); (7) two shapes that join (n1); (8) same as the Sun and Earth (n1) and (9) unsure (n3). In this paper we aim to interrogate similar concepts for learners in the foundation phase. In this instance we attempt to find out how many learners hold a geocentric or heliocentric view of the solar system.

## **2.4. Mental models**

Scholars in cognitive science and psychology have presented numerous types of representation, these include semantic nets (Collins & Loftus, 1975), images (Kosslyn, 1980), schemas (Brewer & Nakamura, 1984) and mental models (Johnson-Laird, 1983). Recently, the progress made in this field has resulted in two representative developments. Knowledge represented as a unified structure of theories (Chi, 2005; Ioannides & Vosniadou, 2002) and knowledge represented as an ecology of independent variables (Clark, 2006; diSessa, Gillespie, & Esterly, 2004). In this study we have chosen the mental models approach to reveal young learners' representations of the earth, moon and sun. Similar to (Brewer, 1989) we use the approach of mental models because it is characterized with a dynamic structure which allows learners to spontaneously create models with the purpose of solving problems, answering questions and identifying learners' intuitive/causal theories as influenced by their underlying conceptual structures. This approach was administered using clinical interviews that served to describe the represented and explained concepts that the learners hold. These various concepts were then used to broadly describe the mental models that the learners hold regarding the solar system.

If a learner is told that "Neil Armstrong dropped a fifty cent coin during his time on the moon" the learners' mental model of the location of the coin after it was dropped will be generated and limited by their underlying conceptual understanding of the theory of gravity on the moon. Given that these mental models are influenced and limited by the learner's underlying conceptual structures, we presume that in order to understand the mental models that learners construct to solve problems or answer questions, gives us important information about the nature of their intuitive theories.

## **3. METHOD**

### **3.1. Sample**

The design of this study a case study as described by (Henning et al, 2006). Participants consisted of twenty isiZulu speaking learners: 10 grade R learners (ranging in age from 5 and 6 years of age) and 10 grade three learners between the ages of 9 and 10 years. Both the purposeful and random sampling technique were used to select the above mentioned participants. We purposefully selected both grade R and 3 learners as our participants and randomly selected 5 girls and 5 boys from the class register of both grades. They were expected to express their concepts of the E-M-S model by selecting from various colours of clay to construct their representations of the Earth, the Sun and the Moon. A series of clinical interviews were conducted at a primary school in Soweto, Johannesburg, to elicit their thinking in relation to the shape, colour and relative positions of the Earth, the Sun and the Moon.

### **3.2. Clinical Interviews**

The questions asked during the clinical interviews were developed and designed to elicit salient concepts in the domain of Astronomy. This section included 3 instructions and four generative questions. According to (Brewer, 1989) generative questions have a far greater potential for providing

information about children’s underlying conceptual structures (p. 542). Through these types of questions learners are expected to explain specific phenomena that they can’t see or get instructions to execute. In order to ensure validity and reliability we adapted the questions from a successful pilot study conducted by Naude (2015). The questions and instructions are explicated below. The interviewer presented the learner with six differently colored strips of clay and asks learners to select from these colours to create the earth, moon and sun respectively and explain why each colour and shape was chosen. Learners were then asked to insert a pin onto their clay model of the Earth and to explain where they think they are geographically on their models and asked to explain their selection. The learners were then asked to show the positions of their clay models in relation to each other. Learners had to explain the movement of these objects. By asking these questions we were particularly interested in finding out if learners predominantly held a geocentric or heliocentric view of the earth. This was an important aspect of the method and the study in general; this is because the answers and explanations of these questions generate data on whether learners’ concepts do indeed change from naïve to normative or whether they remain the same.

### 3.3. Data Capture and Analysis

Individual video recorded interviews were conducted in isiZulu with the learners for between 30 and 45 minutes. The interviews were then translated from isiZulu to English. The data was analyzed using open coding and designed to capture numerous specific responses as displayed by learners.

## 4. RESULTS AND DISCUSSION

### 4.1. Data Analysis Results

In the analysis of the data we compared the responses of the grade R learners with those of the grade 3 learners. In so doing we aimed to identify any changes in the learners’ concepts. Through open coding the data from grade R responses was compared with that of the grade 3 learners by using an excel spreadsheet. The data were placed directly against one another in order to identify changes. The pertinent findings represented in the table below were generated by an extensive analysis of the data collected:

**Table 1: Findings that precipitated from the analysis**

Grade R	Grade 3
1.The earth is flat	1.The earth is a sphere
2.The earth is blue	2.The earth is blue
3.The sun is a yellow circle with rays	3.The sun is a sphere with rays
4.The moon is white and “banana” shaped	4.The moon is blue and “banana” shaped
5.The earth is the center of the solar system (Geocentric view)	5.The earth is the center of the solar system (Geocentric view)

### 4.2. The shape of the Earth

The data revealed that 4 of the learners explained the reason why they created the earth flat was “because it’s a circle”, 3 substantiated their models by stating that is was either a square, round or a

rectangle. The most notable change in the two groups is the move from representing the Earth as a two-dimensional flat disk to representing it as a three-dimensional sphere.

#### **4.3. The colour of the Earth**

Nearly all participants depicted the Earth using the colour blue. In explaining their choice, learners explained that the Earth is blue because they can see it is blue. Their choices were influenced by the observation of the sky's colour. From this we see that learner's observations of the natural world plays an important role in their explanations and gives fodder to their causal reasoning.

#### **4.4. The shape and colour of the sun**

It is evident from the data that both grade R and three learners hold that the sun is yellow with participants FFR4, FMR7, FF34 and FMR6 amongst others substantiating their selections by stating "I can see the sun is yellow". However, more grade 3 learners create a spherical model than grade R. A flat sun concept is prevalent in the models created by our grade R sample. The prevalence of representations that depicted the rays of sunlight remained evident throughout both samples. This representation most likely stems from the habit of drawing the sun with rays protruding from it. This shows how learners represents an abstract concept like radiation as a physical entity. The prevalence in both samples also indicates the resistance of naïve concepts to change.

#### **4.5. The shape and colour of the moon**

In our grade R sample we found that seven out of ten learners stated that the moon is white and the other three selected the blue colour. They all created the moon in what they refer to as a "banana shape" representing a crescent moon. In grade three we find that the number of participants who select the blue colour to represent the moon has increased to 5, with 4 holding a white moon notion and one participant who created a brown moon model. The crescent shaped moon was still prevalent as most grade 3 learners chose to represent the moon in this way. From the explanations given the learners once again stated that their choices were influenced by their observations. Very few learners chose to depict the moon as a two-dimensional circle and none chose a three-dimensional sphere.

These results and those about the earth and sun, compare favorably with those of Blown (2013) who infers that young learners' concepts of the earth and its celestial neighbors are influenced mainly by observation and media such as story books and television.

#### **4.6. The learners' representations of the relationships between the Earth, the Sun and the Moon**

When analyzing the data with regard to the "geocentric view" theme for grade R and 3, we found that 8 out of 20 learners placed the sun directly on top of the earth model explaining that the sun is found in the sky. Nine of the learners placed the sun at a 45-degree angle above the Earth at a distance of approximately 20cm. When asked to show the relative position of the moon 14 participants placed it directly on top of the earth model and 40% of them explicated using the clay models that "when the sun goes down the moon comes up". This reveals to us that learners in both grade R and 3 hold a geocentric view of the solar system. As hypothesized by us and described by diSessa (2006), the change that is present does not develop from "naïve" to normative. This could be attributed to the lack of time allocated to these concepts in the life skills curriculum.

### **5. RECOMMENDATIONS AND CONCLUSION**

#### **5.1. Recommendations**

From the findings we recommend that the amount of time teachers spend teaching these concepts in life skills should be interrogated. A possible reason for the naïve concepts remaining prevalent in grade 3 could reside in the content knowledge of the teachers. We propose that further studies be made in determining the concepts that foundation phase teachers hold regarding natural phenomena. It would be interesting to see the responses of foundation phase teachers to the same clinical interview. In order to ascertain the learning of science concepts in the foundation phase we propose that longitudinal studies should be conducted to track the conceptual change that occurs related to science concepts.

## 5.2. Conclusion

The study aimed to identify if there was any change in grade R and 3 learners concepts of the E-M-S model. We found that there were changes in these concepts but that the mental models related to the solar system remained geocentric. It was noted that in South Africa there is a gap in our knowledge about what scientific knowledge learners hold in the foundation phase. The findings showed that there isn't a noteworthy difference between the representations of learners regarding the sun and moon and their relative positions in the solar system. However, learners don't have to be 'little Einstein's' to develop science skills and knowledge, as they use naïve concepts and intuitive theories which are based on their emergent ideas and prior knowledge. What they do need is sufficient guidance as they explore, experience and view the world in context to allow them to form naïve concepts that can develop into normative concepts. This study argues that it could benefit learners' learning of science concepts if more time is spent teaching these concepts and would help them move along their cognitive journey from naïve concepts to normative understanding of the natural world.

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