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The reflective experimental construction of meanings about the shape of the Earth and the alternation of day and night*

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Abstract

The purpose of this paper is to describe and analyze the process of construction of meaning about the shape of the Earth and the alternation of day and night, which is inherent to the practice of experimental science teaching. This teaching practice was gradually done by the researcher in a 1st grade class of a Portuguese primary school. The class was composed of 18 students, ten girls and eight boys, with ages ranging from six to seven years old. The analysis of the meaning construction process focused on the class diary prepared by the researcher, based on the field notes and audio recordings made during the participant observation in the classroom. The goals of the interpretive analysis of the diary were as follows: a) identifying the students' initial ideas expressed during class about the shape of the Earth, b) characterizing the processes that promote the construction of knowledge about the topics under study; c) and presenting the learning that takes place during class. These instances of learning described in the class diary, combined with the results of a true or false questionnaire, suggest that most students developed a good understanding about the shape of the Earth and the alternation of day and night.

Keywords: Conceptual Development, Evolution Understanding, Parent-Child Conversation, Informal Learning Environments, Science Education.

Introduction

The identification of the children's intuitive ideas about various science topics was, over the last three decades, a powerful research guideline in the field of cognitive science and science education. Several studies have demonstrated that children construct, from an early age, intuitive mental models about the shape of the Earth and the alternation of day and night that diverge from the scientific model (Nussbaum, 1985; Vosniadou & Brewer, 1992, 1994; Fleer, 1997; Siegal, et. al, 2004; Blown & Bryce, 2007; Özsoy, 2012). As an example, Vosniadou and Brewer (1992) identified, in primary school children in the U.S., five alternative mental models of the Earth: the

* This manuscript and the case study about the shape of the Earth and the alternation of day and night are an integral part of the author's doctoral thesis.

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rectangular earth, the disc earth, the dual earth, the hollow sphere, and the flattened sphere.

Nevertheless, the vast knowledge produced by such lines of research, especially within science education, has garnered criticism from some constructivists as regards its diminished influence on the improvement of the children's learning and teaching. Matthews (2000) claims that this theoretical knowledge *"*offers very little guidance for teachers who are in the classroom trying to teach Science contents" (2000, p.270). In the same sense, White states that "...although the research on alternative conceptions has sparked interest in the content, it has not yielded clear advice about how to teach different topics" (1994, p.255).

In many countries, the primary school science syllabuses, while they recommend activities based on inquiry methods, hands-on activities, dialogues, discussion and collaborative working, do not include any information on how teachers should implement such activities in their approach to the various teaching contents (Eurydice, 2011). Despite all efforts, in many countries these curricular guidelines still do not bear the necessary influence to change the pedagogical practices of teachers. For example, Martínez and Díaz (2005), when referring to the Spanish educational context, mention that the curricular guidelines for primary education have been advising on more innovative Science teaching, based on an active and constructive role for the student. However, the reality in that country's classrooms is quite different, as the authors point out: "studies and polls carried out show that Science teaching as a transmission is still predominant, and it is based on blackboard master-classes, on the school textbook and the solving of closed problems related to the studied themes" (2005, p. 243).

The promotion of inquiry-based Science teaching is a highly demanding challenge, which calls for major changes in the teaching practice (Harlen, 2010; Brand & Moore 2011). Indeed, most primary school teachers have insufficient scientific knowledge and are not familiar with these teaching strategies, thus depriving their students from the opportunity to engage in relevant and meaningful learning (Harlen, 1999; Lee, et. al, 2004; Appleton, 2003; Brand & Moore, 2011). Harlen (1999), in analyzing several studies about the teachers' understanding of Science conducted during the 1990s in countries such as the USA, England and Scotland, concludes that primary school teachers have a low level of confidence about teaching Science and understanding science concepts. These insufficiencies have implications for the students' learning opportunities, and are commonly associated "with restricting classroom activities to following instructions and inhibiting creativity and questioning" (Harlen, 1999, p.81). Faced with those limitations, Appleton (2003), in a study performed with Australian pre-service teachers, states that some teachers avoid teaching Science or rely on activities with little scientific content, which are usually conducted as a demonstration. Other teachers, however, find support in Science textbooks and worksheets, whose hands-on activities are typically presented with step-by-step instructions (Huber & Moore, 2001). The way these activities are generally introduced in textbooks and developed by the teachers does not foster intellectual engagement on the part of the students. Instead, it leads to much physical action and little mental activity (Harlen, 2007), and it tends to give students a distorted and fallacious view of the nature of Science (Huber & Moore, 2001; Levinson, 2002). Teachers should build learning opportunities and encourage students to engage in genuine inquiry activities or, as mentioned by Jorgenson (2005) in "hands-on minds-on activities".

In Portugal, the experience of more than three decades has shown that the introduction of Science themes and new approaches to school knowledge construction in the Primary Education programs has failed to produce any significant effects in the renovation of pedagogical practices and subsequent improvement of the quality of student learning (Sá, 2002a). Children in primary schools still do not have opportunities to develop the “experimental attitude”, highly praised in the Science component of the Environmental Studies curricular area (Ministry of Education, 2004), which leads to the neglect of important domains of knowledge construction and skill development that are necessary all across the different curricular areas (Varela, 2012). Memorization and repetition activities are overrated, and the students keep performing stereotyped, meaningless tasks (Roldão, 2003). In this learning environment, the student takes on a passive role, fundamentally limited to the accumulation of knowledge. Learning loses relevance, and its personal and social use becomes ineffective.

The contact with schools through interventions that we have been conducting in primary school classrooms (Sá & Varela, 2004, 2007) has allowed us to verify that children do not usually have opportunities to conduct practical or experimental science activities which: potentiate their intellectual, personal and social development; stimulate thinking and conceptual understanding (Zohar, 2006); promote language use as a tool for constructing and sharing knowledge (Aleixandre, 2003; Rivard, 2004; Ibáñez & Alemany, 2005); stimulate discussion and argumentation around the students' ideas and the experimental evidence they produce (Naylor et. al, 2007); promote in students an active, autonomous regulator and reflective role on their own learning (Cleary & Zimmerman, 2004); and develop positive attitudes towards Science learning in children (Harlen, 2007). This reality is perceived also by Costa, who referring to practical and experimental Science activities states the following:

> “(…) the way that they have been used has contributed nothing at all to the learning of scientific concepts by students, or to the understanding of the processes used by Science or even to the acquisition of transversal skills. (…) they are rarely used in ways that develop skills of observation, inference, communication, interpretation and planning. Instead, they are more often used as a treat for students "if there is time left" (which rarely happens), or, at best, as an attempt to engage the less motivated students” (2006, p.33).

Thus, primary school students are rarely involved in a genuine process of scientific meaning construction and development of cognitive resources, which are based on a direct relation to concrete objects, manipulating, feeling, experiencing them and reflecting on the observations they make and the actions they carry out with them. Without this knowledge and resources, the students will lack the foundations on which to build essential skills for new forms of learning, which are necessary all throughout the different curricular areas and that will ensure them a participating and informed citizenship in the future (Sá & Varela, 2007).

In this context, we have been developing for over a decade and a half a research and intervention work in the classroom, geared towards an experimental reflective approach of Sciences in the early years of schooling (Sá, 2002a; Sá & Varela, 2004, 2007). This paper is situated in the continuity and deepening of this perspective of teaching and research, and its content is a small part of a study conducted by the author (Varela, 2012).

Objectives

In this paper the process of meaning construction is described and interpreted through the study of "the shape of the Earth and alternation of day and night", aiming at specific purposes: (a) identifying the students' initial ideas about the shape of the Earth, (b) identifying and characterizing processes that stimulate classroom construction of meanings about the topic under study, (c) and presenting the learning that takes place during class.

Reflective Experimental Science Teaching – R EST

REST places great emphasis on the stimulation of the student's reflective thinking skills, integrating and intensifying, in an interdependent manner, the development of cognitive processes and conceptual comprehension (Miras, 2001; Sá 2002a; Zohar, 2006; Harlen, 2007). It is an approach to Science teaching in which:

> "(...) experimental activities are not simple manipulations executed mechanically by imitation, or following instructions provided by the teacher or described in a textbook. On the contrary, they are actions with strong intentionality, closely associated with the student's mental processes. It is this combination of thought and action that leads to higher quality learning" (Sá, 2002a, p.47).

Learning takes on a dynamic and evolving nature of (re)construction of socially constructed meanings, which depart from the ideas that students construct in their personal and sociocultural experiences. When explained in the social context of the classroom, these are subject to a generative and reconstructive process of new meanings with greater power to explain physical and natural phenomena (Sá, 2002a; Harlen & Qualter, 2005; Harlen, 2007). Learning starts from:

> "relevant problems and personal ideas that describe and interpret them, in order to gradually construct, through a process of critical contrast with other ideas and with reality phenomena, a school knowledge that is socialized and shared by means of processes of conceptual change and evolution" (Porlán, 1998, p.101).

In the teaching and learning process, students confront their ideas and expectations with the experimental evidence produced (Harlen & Qualter, 2005; Harlen, 2007) in a methodical, organized and intentional way. The student thus becomes gradually skilled in the process of coordinating personal theories with evidence (Kuhn, et. al, 1988), aiming for a progressive harmonization and conformity of the new theories with the physico-natural world. However, the perspective of conformity between theories and experimental evidence is different for each subject, i.e. "the same experience or the same observation are experienced, seen and understood very differently by different children" (Charpack, 2005, p.29). For this reason, the meanings constructed by way of physical interaction with materials and objects are the subject of discussion and reflection in small and large groups, so that the critical selection and negotiation leads to higher-level meanings, shared by a growing number of students (Naylor et. al, 2007; Domínguez & Stipcich, 2009). It is in the process of social interaction that the different interpretations of physical experience are confronted, negotiated and reconstructed and it is in that interactive process that the different meanings are defined and refined (Candela, 1999).

In REST, the creation of collaborative contexts has a particular importance, as they facilitate the emergence and exchange of different meanings and explanatory interpretations for the various learning situations (Larkin, 2006) and stimulate the joint construction of scientific meanings (Palincsar & Herrenkohl, 2002). We thus recognize the importance of promoting spaces for collaborative mediation and negotiation of meanings, which stimulate students to share opinions among them and with the teacher, to defend their points of view and to justify and/or refute the arguments presented (Henao & Stipcich, 2008). The discussion generated in the classroom provides children with the awareness of their own ideas, the different ideas and ways of thinking that exist in the group (Larkin, 2006; Harlen, 2007) and the need to review and/or restructure their ideas, in face of other more plausible and consensual ones that appear in the social context of the class (Varela, 2012). Through this intense collaborative activity, children also learn, by the action of others and the teacher, to monitor and auto-regulate their own thought and gain access to a wider range of problem-solving strategies (Mercer & Littleton, 2007).

Thus, the teaching and learning process is aimed at encouraging students to reach the highest limit of their potential, i.e. their "zone of proximal development", proposed by Vygotsky, allowing for the awakening of "a variety of internal development processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers" (Vygotsky, 1978, p.90).

From sociocognitive activity, which takes place alternately in small and large groups, emerges the need for more refined observations of the evidence, as well as for the repetition of experimental procedures, which are accompanied by a more reflective attitude from the student. This attitude brings forth new ideas, propelling the discussion to higher quality thinking levels, inducing metacognitive and learning self-regulation skills in students (Larkin, 2006), while also favoring a high degree of transference of the learning acquired to new contexts (Georghiades, 2006) and the autonomy of students (González, & Escudero, 2007). Individual meanings, when explained, reflected upon, contradicted and negotiated will result in a smaller number of meanings, now enriched and shared by a large group of students (Sá & Varela, 2004).

REST lends special importance to the role of oral language as an instrument of communication and construction of scientific meanings (Català & Vilà 2002; Aleixandre, 2003; Maloney & Simon, 2006). Students often resort to written language, which requires greater awareness of the mental operation one executes, developing a process of inner speech within the subject himself (Vygstsky, 1987). Writing implies thinking about whatever is the object of the writing, organizing ideas, establishing connections between them, selecting the best words and articulating them correctly. Indeed, when we encourage students to develop the regular habit of writing about the experimental activities, we are simultaneously giving continuity to the reflective process, promoting the highest level of learning within their reach.

REST implies renewed roles for students and teachers. In this teaching practice, students:

- explain their ideas and ways of thinking about questions, problems and phenomena;
- argue and counterargue among themselves and with the teacher regarding the validity of their ideas and strategies;
- mentally construct simplified research plans with their peers;
- carry out the resolution plans and strategies for the problem situations they are confronted with;
- submit personal ideas and theories to the critical confrontation of their peers and to the test of evidence by resorting to the scientific processes;
- keep written records of their observations and evidence data, as an integral part of the exploration of practical and experimental situations;
- critically assess the conformity level of their theories, expectations and predictions with the ideas of others and with the experimental evidence they produce;
- negotiate different personal perspectives about evidence, questions or problems, aiming for the construction of enriched and socially shared meanings (Sá & Varela, 2004).

The teachers, for their part, take on a role of high activity, reflection and strong pedagogic intentionality: a) in the interpretation of the actions carried out by the students and in the meanings that are generated and reconstructed in the classroom, in order to regulate and re-feed the students' mental constructive activity; b) in the stimulation and mediation of the students' interactions with the experimental evidence they produce with their peers; c) in the promotion of an active participation by the students, providing them with the necessary stimulus for verbalization, action and reflection; d) in the valorization and regulation of the discussions that arise around the students' interventions; e) in the creation of an environment of collaboration, accountability and freedom of communication; f) through continuous and recurrent reflective questioning, which stimulates the students' thoughts and actions (Varela, 2012). This questioning will provide, at each moment, adequate help to the needs expressed by students in order to escalate to progressively higher levels of thought and learning (Rojas-Drummond & Mercer, 2003; Chin, 2006; Molenaar, et. al, 2011).

Method

The study is developed according to an action research approach within the theoretical framework of interpretive research, applied to the study of teaching and learning processes in a classroom context (Erickson, 1986; Guba & Lincoln, 2000).

A 1st grade class from a Portuguese primary school located in the outskirts of the city of Braga, composed of ten girls and eight boys (n=18) with an average age of 6.25 years, was subjected to a process of REST. Distributed over one school year, 20 lessons were taught addressing various science topics within the curricular area of Environmental Studies, amounting to a total of 40 hours of intervention in the classroom.

Each lesson, which corresponds to one action research cycle, begins with a teaching and learning plan that takes the form of a starting “curricular hypothesis” (Porlán, 1998) to be implemented flexibly, according to the teaching and learning processes that are generated and promoted in the class reality. The teaching and learning plan pertaining to the curricular topic on the shape of the Earth and the alternation of day and night was prepared according to the didactic sequence suggested by Vosniadou (1991) and Vosniadou et. al, (2004)[1]. According to these authors, in learning basic concepts of astronomy there should be an interrelation between the understanding of the spherical shape of the Earth, the rotation of the Earth with regard to the apparent movement of the Sun and the explanation of the alternation of days and nights.

At the time of the pedagogic intervention on "the shape of the Earth and the alternation of day and night", the students had already benefited from the cumulative effect of 32 hours of REST. The classes were taught by the researcher, who, in collaboration with the class teacher, played the role of both a researcher and the teacher. Thus, there was an attempt to capture and understand the processes of generating and (re)constructing scientific meanings promoted in the classroom, in a social learning context. The researcher-teacher's attention was especially focused on the interpretation of the meanings manifested by students in the moments of communication, action and interaction with their peers and the researcher, and on how these meanings were being reconstructed and negotiated within the class.

The data generated in the action were collected using two complementary methods, namely the fieldnotes made by the researcher and the audio recordings of the lesson. This raw data were later materialized in the form of detailed narratives of the most relevant events that occurred in the classroom – the class diary. These constituted the principal method of recording data and, simultaneously, a strategy of reflection and modeling of the teaching and learning process (Sa, 2002b; Zabalza, 2004).

The lesson, as a referential unit of analysis represented in the class diary, is therefore composed of a sequence of learning moments that correspond to more particular units of analysis. Each unit of analysis is the bearer of a specific sense that distinguishes it

[1] See the full teaching and learning plan, in Portuguese, in Sá and Varela (2007) or part of the plan, in English, in Varela (2012).

from other units – "unit of meaning" (Ratner, 2002), in the evolving and interactive process of constructing scientific meanings. In each diary we began by identifying the sequence of units of meaning. We then carried out the interpretive analysis of the meaning of the data concerning each identified unit and the definition of its central theme, based on that analysis.

The data contained in the diary represent a sample of the diversity of meanings that the students construct in the classroom, while interacting with their peers and the teacher, as well as during the activities conducted. A true or false questionnaire about the "shape of the Earth and the alternation of day and night" was therefore applied in order to attain a more reliable perception concerning the level of individual learning achieved by the students. In view of the dynamic character of the constructive process of meanings - the range and depth of learning only occurs after some time (Coll & Martín, 2001) -, the questionnaire was applied at two different moments, i.e., immediately after the lesson and after three weeks.

The interpretive content analysis of this class diary is the starting point to interpret the process of teaching and learning promoted in the classroom about "the shape of the Earth and the alternation of day and night".

Interpretive quality criteria adopted in this study

The regular presence of the researcher with the children in the classroom for various periods of time, in an accumulated total of 32 hours until the lesson about "the shape of the Earth and the alternation of day and night", ensures a "prolonged involvement" (Guba & Lincoln, 2000). The researcher's prolonged presence affords a progressive construction of a relationship of empathy and openness with the students. This relationship is essential so that the research subjects may share their views with the researcher. In these circumstances, the researcher can access multiple perspectives of meanings from the students' perspective, and can linger on them, analyzing them in depth and detail in order to derive a better clarification and understanding in the context in which they occur (Pérez Gómez, 2005).

"Listening to participants", proposed by Guba and Lincoln (1989), can hardly be sustained in this study. The subjects in this study are 1st grade students. From our point of view, it is not feasible to ask six and seven-year-old children to audit the representations that the researcher generates from the meanings they constructed in the teaching and learning process. Thus, while maintaining a certain parallelism to "listening to participants", a process of recurrent "validation" was adopted in the identification of the students' constructions. This consisted of ascertaining the meaning of what children say and do, at the time and in the context, through a systematic interaction with them. Thus, the researcher may put his/her inferences to the test, in a close and situated manner, because he/she is an active subject in the observation context (Erickson, 1986).

The use of audio recording is a procedure that lends more credibility and veracity to the qualitative data collected. Audio recordings afford the researcher greater availability to reflect and interact with the subjects in order to ensure that the meanings referred by them are correctly interpreted and represented (MacLean, et. al, 2004). Moreover, in situations of ambiguity or inconsistency (uncertainty) regarding the meanings inferred in the classroom, the recourse to a later hearing of the recording can clarify the intended meaning from the original source (Fasick, 2001). From our point of view, revisiting the original data, by hearing the recordings at a later time, allows for a novel outlook, distanced from the data itself and the interpretations made in the course of the participant observation, in order to construct a representation of the studied reality as accurate as possible.

The combination of the preceding techniques allows for the collection of "abundant information" (Carrasco & Hernández, 2000). After class, to best take the advantage of fresh memory, the class diary was written on the basis of the audio recordings and the field notes. The diary includes verbatim transcripts of what the children say in meaningful moments of interaction, events of non-verbal nature and emotional aspects not captured by audio recording. It represents the events generated in the classroom by means of a thick description (Denzin, 1989). A rich and detailed narrative of the observations increases the credibility and plausibility to an external reader regarding the data and the inferences made. Furthermore, the act of creating a narrative increases the confirmability of the study, since it allows us to distance ourselves from our judgments, premature interpretations and provides an opportunity to open our work to the inspection of others (Newman, 2000).

The analysis of the class diary includes segments of raw data so that an external reader can judge the credibility and neutrality of the inferences made from their meanings (Lincoln & Guba, 1989; Ratner, 2002). This constitutes a relevant factor for the confirmability criterion, i.e. to verify that we are not in the presence of arbitrary constructions imagined by the researcher.

Results

Interpretive content analysis of the class diary about the shape of the Earth and the alternation of day and night

The teaching and learning activities begin by identifying what students think about the shape of the Earth. Students are asked to draw the shape of the Earth.

What ideas do children present about the shape of the Earth?

The interpretation of the meaning of the drawings takes place in two moments: i) in class, through observation, communication and discussion generated around the intended meaning of the drawings; ii) after class, through a more detailed analysis of the content of the drawings and the arguments presented to the class by the students. We identified three categories, whose content represents qualitatively different ideas about the shape of the Earth:

A. Most students' drawings evidence the idea that the Earth is flat. At the bottom of the drawing, the Earth extends down and to the sides. On the surface, the students drew houses, trees, people, etc. Above that, there is the sky and/or space, with some birds, clouds, stars and the Sun. This is the most primitive conception of the shape of the Earth identified in the class (11/18; 61.1%).

Figure 1. Gabriel; 6.5 years

B. A second category of drawings apparently considers the idea that the Earth is round. However, what is relevant about the sphere on the drawing is what is inside it: i) a well-defined area at the bottom, which is round on the bottom and flat at the surface. That is where the trees, houses and people are; ii) the top part corresponds to the sky and/or space, where some birds and flying insects, the stars and the Sun are drawn. Although these students claim that the Earth is round, it seems very plausible that this model results from the incorporation of the scientific information

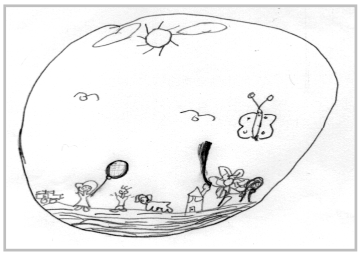


Figure 2. Francisca; 6.4 years

regarding the sphericity of the planet into the previous model. The Earth itself would be the bottom part, with the flat surface, whereas the top part would correspond to the sky and/or space. Phrases like "our country is inside the Earth" suggest that the word "Earth" can either take on the meaning of the cosmic body we inhabit, or that of a cosmic entity that contains the Earth and the space inside it. Reinforcing this interpretive hypothesis is the fact that the expression "inside the earth" does not, in any way, mean "below the Earth's crust", but rather "inside" the sphere on the drawing (3/18; 16.7%). This interpretation is further validated by other authors who have identified the same concept in children belonging to the same age group (Nussbaum, 1985; Vosniadou, et. al, 2004). Vosniadou et. al, (2004) call this model "hollow Earth", as it is a synthetic model derived from the children's attempts to incorporate the scientific information that says the Earth is a sphere into the initial concept that the Earth is a supported and stable plane.

C. In a third category of drawings, the Earth appears as a spherical body surrounded by space, where the stars and the Sun are drawn. On its surface there are countries, continents and oceans. For these students, people live on the surface and not "inside" the Earth: "it's on the outside"; "people walk up here on the land"; "they also ride boats on the sea"; "and swim and ride water scooters" (4/18; 22.2%). The meaning of the drawing is communicated to the class as follows: "I made the Earth round, seen from Mars. In space I drew the Sun and the stars, and here (on Earth) I drew the islands, the seas and people's lands (countries)".

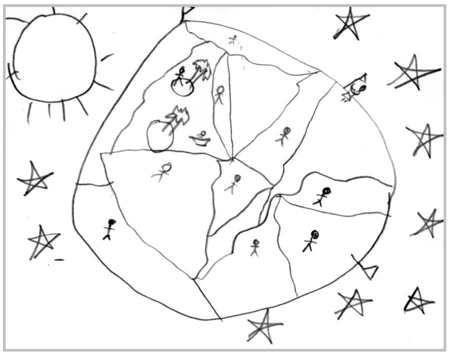


Figure 3. Sara; 7.1 years

Such ideas are in line with those identified by Nussbaum (1985) in Israeli students, aged between 8 and 14 years, about the Earth concept: the shape of the Earth, space and gravity. The author identified five notions that, from 1 to 5, correspond to a conceptual progress, from the most egocentric and primitive vision to the most de-centered and scientific one. Notions 1, 2 and 3 consider only the shape of the Earth and the nature of the sky/space:

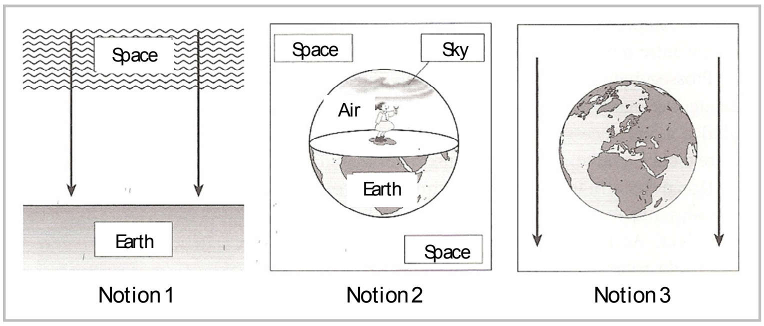


Figure 4. Notions about the shape of the Earth and the nature of the sky/space – adapted from Nussbaum (1985).

Our drawing categories (A, B, C) suggest a high level of parallelism with notions 1, 2 and 3 identified by Nussbaum (1985). The author found that approximately 80% of children aged eight years, in the 2nd grade, are distributed among notions 1 and 2.

A. Development of ideas about the shape of the Earth: from the flat model to the spherical model.

From the previous ideas that emerged in class it is intended that students, in small and large group, reflect on them and submit them, by way of discussion, to critical confrontation before colleagues and before the scientific model (photographs of Earth taken from space and earth globe), in order to develop a better knowledge and understanding of the shape of the Earth.

A_1. Communication and discussion of the meanings expressed in the drawings.
Passage from class diary:

> “I did the Earth, which is round” Francisca (6.2 years). "Francisca put things inside it" (Lionel; 6.9 years). "She put butterflies, the Sun and the clouds inside it" (Júlia; 6.9 years). Francisca's drawing falls into category B. Mafalda (6.4 years) clearly expresses the meaning of her drawing (category C): "I made the Earth round, seen from Mars. In space I drew the Sun and the stars, and here (on Earth) I drew the islands, the seas and people's lands (countries)". Gabriel (6.3 years) drew a flat Earth (Category A): "I did the clouds, a boy, the Sun..." He also says: "the Earth is under the boy." I ask him if the shape of the Earth in his drawing is flat. With a sad look, he says “yes”, but he recognizes that it is not flat: "No. I made it flat like this, but now I think it's round". Others also become aware that their drawings were not in agreement with the idea that the Earth is round: "Luís said that the Earth was round, but he didn't make it round" (Pedro; 6.3 years); "I didn't either, I thought it was flat" (Susana; 6.6 years), "Mine is not round" (Lionel).

Oral communication is aimed at sharing and confronting the meanings expressed in the three previous models, so as to subject them to critical review and promote their re-elaboration by others. In this process we observe the following:

i) the model of pseudo-sphericity of the Earth is strongly criticized with a hint of irony: "Oh look, she put things inside it; she put in butterflies, the Sun and clouds";

ii) the flat Earth model, confronted with the spherical model, generates some dissatisfaction and a critical attitude towards their own drawings and those of others, now rendering the notion of sphericity of the Earth far more plausible: “I made it flat like this, but now I think it's round"; "Luís said the Earth is round, but he didn't make it round".

A_2. The class faced with the spherical model of the Earth.

The students are unanimous in admitting that the spherical model (Category C) is the one that best represents the shape of the Earth. However, conflicting thoughts emerge between the most primitive meaning (flat Earth model) and the socially accepted meaning (spherical model), which demonstrate the difficulty in reconciling sphericity with the perception of the Earth's flat surface resulting from direct observation.

B. The Earth: development of a more comprehensive and richer meaning.

The students' initial ideas and ways of thinking are now subject to confrontation with empirical evidence: a photograph of the Earth taken from space and the Earth globe.

B_1. The photograph of the Earth and the Earth globe.

The comments about the observation of the photo begin by focusing on the Earth's spherical shape. However, color is a piece of information that stands out in their comments. The shade of blue is identified as the "seas" and, surprisingly, the white spots are associated with clouds and the ice at the poles. This inference requires a certain level of abstraction: in everyday life, students see the clouds from the Earth, but now they are identified from another perspective – that of someone who sees the Earth from a given location in space.

When the students' attention is focused on the globe, most of them know its name and prove to understand that the Earth globe represents a miniature of the Earth.

***B_2. What are the* similarities between the photograph of the Earth and the globe? Passage from the diary:**

> Children state without hesitation: "The shape is the same" (Júlia; 6.8 years), "they are both round" (Sara; 6.9 years); "it's the shape"; "it's the same" (other children). Some also recognize a few differences: "it's just that, in the picture, the blue is darker and there (globe) it's lighter" (Gabriel; 6.3 years). "This was taken from very far away" – argues Lionel (6.9 years), referring to the different shades of blue. When asked about the differences, they realize the following details: "The lands here (the globe) are neater and we can see them better" (Sara); "and here it seems they are more spread out, here (the photo) we can see the clouds" (Lionel); "it's as if it were space" – adds Sara.

The groups easily identify the similarity between the spherical shape of the Earth on the photo and on the globe. In that comparison, they also identify some differences between the reality of the Earth in the photograph and its representation on the globe model. In the photograph, the Earth is distinguished by: i) the darker shade of blue; ii) the lack of identification and contouring of the "lands", i.e. the continents and the countries contained therein; iii) the presence of clouds and the cosmic space around the Earth seen in the photograph.

***B_3. A renewed outlook on the drawings of the shape of the Earth*. Passage from the diary:**

> The children's attention is again focused on their drawings. Those who drew a flat Earth recognize once again that the Earth is round: "mine is not round" (Lionel; 6.9 years); "the Earth here is round (photo) and here it isn't" – says Gabriel, pointing at his drawing. I ask the class what they now know about the shape of the Earth. They assertively answer that "it is round" and Gabriel states that it looks like a ball. "It looks like a ball, but it's always spinning" says Júlia.

The idea of the Earth's sphericity is very mature in the class. For some students, the contrast between that knowledge and the less evolved ideas expressed in the drawings promotes greater awareness of their own learning. Only a few verbalize that increased awareness, but by doing it in a social context they are not only consolidating their ideas, but also promoting the intra-personal processes of assimilation of that learning in the other children. Verbalization favors the construction of more elaborate formulations of those same ideas, as in Júlia's case: "It looks like a ball, but it's always spinning".

C. Day and Night

C_1. What is day?

Within the small groups, students are encouraged to think about what day is[2]. There is a reference to *morning* as being daytime, an idea that can stem from the Portuguese morning greeting "bom dia" (good day). It is by opposition to that idea that they realize that the concept of day includes morning, noon and afternoon. After being questioned again, they now acknowledge that the elements Sun and light are subsumed in the

[2]It is intended that children develop the notion of day as the period of time during which a given location on Earth is illuminated by the Sun, i.e., the period between sunrise and sunset (natural day). That notion and the previously acquired meaning of the sphericity of the Earth will support the later development of the comprehension of the day-night alternation, as a result of the Earth's rotation movement in the presence of the Sun.

definition of day. It is said that the day begins with the sunrise. Some answers seem to contemplate the idea that the Sun is always visible during the day. This idea is subject to discussion. Students demonstrate an understanding of day as corresponding to the period of time during which the Sun illuminates a location on Earth, even if it is covered by clouds for whole days.

C_2. What is night?

In answers to questions about what night is, the following ideas emerged: i) they begin by making reference to darkness; ii) the darkness is a consequence of the absence of the Sun; iii) the absence of the Sun during the night is explained by some children with ideas of an animist nature – the need for the Sun to *"go away to rest or sleep"*[3]; and iv) in contrast, others claim that the Sun stays in space, in a different relative position, illuminating other parts of the planet. This is quite an evolved idea: it acknowledges the simultaneity of day and night in different locations, as a result of the Sun's relative position to those places.

D. Day and night in the Earth model – The Sun, without the Earth's rotation.

D_1. Identification by analogy of what the globe and the flashlight represent.
Passage from the diary:

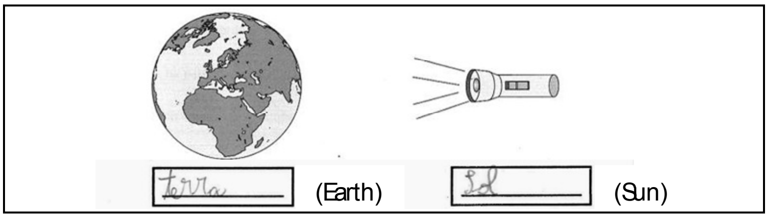
> The children's attention is again focused on the globe on the desk. They have no difficulty in recognizing that "it's the Earth in miniature". I show them a flashlight and some immediately associate it with the Sun: "It's the Sun" (Pedro; 6.2 years); "if you turn it on, it seems like the Sun" (Lionel; 6.9 years). Others also refer to the Sun and Sara adds: "it will give light to the Earth".

The students identify by analogy what each of the objects represents: the globe – "it's the Earth in miniature" – and the flashlight – "it's the Sun"; "if you turn it on, it seems like the Sun"; "it will give light to the Earth".

D_2. Elaboration of records.

The students proceed to the individual recording of what each object drawn on their record sheet intends to represent, i.e., the Earth and the Sun.

❑ I write in the boxes what each object represents.



Francisca (6.2 years)

Figure 5. Learning record: the globe-flashlight versus Earth-Sun analogy.

[3] It is interesting to verify that this idea has also been identified by other authors. For instance, Fleer (1997), in a study with Australian aboriginal children aged four to eight years, found a similar conception when, during the interview, she posed the following question to the children: why is it dark at night? Some answers explained the occurrence of night with the fact that the Sun went away or went to sleep, also relating night to the appearance of the stars and the Moon. However, in most of the answers given by children, according to the author, there is an animistic view of the Sun. According to the author, this conception tends to reflect expressions that children hear in everyday life ("the Sun has already gone away"), or the perception that the Sun descends over the horizon as night falls.

D_3. It is daytime on the part of the Earth that is lit by the Sun and nighttime on the part of the Earth that is not illuminated by the Sun. Passage from the diary:

> "Imagine the Earth is in the dark, what must we do to have daytime on the Earth?" – I ask. Everyone agrees that we have to turn on the flashlight and some state: "now it's daytime". "In what part of the Earth is it daytime?" – I ask. Children answer that it is in the part of the globe that is facing the flashlight: "on the part that is lit" (Bruno; 6.9 years); "it's the one that has the light" (Several). "And on the other side of the Earth, what will it be?" – I ask. Without hesitation some answer: it is nighttime. Mafalda looks pleased to see her previously expressed idea confirmed and states: "On the Sun's side it is daytime and on the other it's nighttime, the Sun does not get there and it goes dark".

D_4. Collective construction of a sentence about day and one about night.

In the discussion, the students show a good understanding of the notion that it is daytime on the part of the Earth facing the Sun, hence receiving light; and that it is nighttime on the part of the Earth that is opposite the Sun, which is in the dark. In class discussion, the following sentences are agreed upon about day and night, and are then written on the individual records: "it's daytime on the part of the Earth that is facing the Sun"; "it's nighttime on the part of the Earth that is not facing the Sun".

E. Earth Globe: from day to night in Portugal.

Our country is situated in the part of the globe illuminated by the flashlight (Sun) and therefore it is day in Portugal.

E_1.What must we do to have nighttime in Portugal? Passage from the class diary:

> The children answer: "We must try to turn the Sun to the other part" (Mafalda; 6.4 years); "turn the Sun" (Emanuel; 7.2 years); "the Sun has to go to the other side" (Júlia; 6.8 years); "we must turn the Sun" (Rui; 6.6 years); "we have to turn off the flashlight and put it on the other part" (Joana; 6.7 years); "when it is too sunny, it tilts a little" (João; 6.8 years). Among these answers, Gabriel and Bruno are the only students to contemplate the possibility of rotating the Earth: "We must rotate the Earth, the Earth is always spinning" (Gabriel; 6.3 years); "we must turn the Earth" (Bruno; 6.9 years). Mafalda argues: "we must put the Sun on the other part so that night comes over here" – the side where it was daytime. Gabriel does not accept Mafalda's or the other classmates' ideas and insists: "it's spinning the Earth, it's always spinning". I point out that there are two different ideas in the classroom: some say that the Sun (flashlight) must move around the Earth (globe) and others say that the Sun stands still and the Earth must spin around itself. Gabriel defends his idea before the class once more. For a few moments they remain in silence. "What do the others think?" – I ask. Bruno insists: "it's the Earth". Other children begin to support that idea: "it's the Earth that rotates, it's like a ball. Sometimes we kick it and it starts to spin" (Júlia; 6.8 years). But others again state that it is the Sun: "I think that it's the Sun that goes around the Earth" (Sara; 6.9 years); "me too" – says Rui. The students are divided. Asked to raise their fingers, ten children think that it is the Sun that must rotate around the Earth and eight think that it is the Earth that rotates around itself.

The answers are mostly supportive of moving the flashlight (the Sun) around the globe (Earth) so as to turn day into night in Portugal. This idea is spontaneously constructed by the students as a result of the observation of the changing position of the Sun throughout the day in relation to where they are – the apparent motion of the Sun. Only two children say that it is necessary to rotate the globe around itself – the Earth's rotation movement. These differing opinions generate intense discussion and promote participation by other children, who explicitly favor the notion of the Earth's rotation movement, as in Júlia's case. After the discussion, the class is divided (Earth's rotation: 10;55.6% vs. Movement of the Sun: 8; 44.4%).

F. Apparent movement of the Sun.

F_1. The illusion of movement of a static body when carried by another body in motion.

The students show an understanding of the illusion of backward movement of the "trees", "ground" and "houses" in relation to the automobile they are riding in. These family situations, evoked and recreated in class, enhance the comprehension of what is apparent movement. But will students be able to mobilize that knowledge and apply it to the apparent motion of the Sun? The answer appears in the following pedagogical approach.

F_2. The illusion of movement of the Sun as we are carried by the moving Earth. **Passage from the diary:**

> The children are encouraged to think about the following question: "so, is the Sun moving?" – I ask. Again, no one supports the idea of the Sun moving around the Earth. However, some evolve into a mixed idea: "It's the Sun and the Earth" (Pedro; 6.2 years), "I think the Earth moves, but the Sun moves everywhere" (João; 6.8 years). Others are now beginning to support the idea of the Earth's rotation: "it's the Earth" (Several) "it's the Earth that is always spinning" (Francisca; 6.2 years); "the Earth is a ball and it's always spinning and it seems like it's the Sun that is moving" (Mafalda; 6.4 years). Sara intervenes and states: "as the Earth moves slowly and we are here in our place, it seems like the Sun is moving. But it's not, it's the Earth". Sara is very excited at this point and continues to explain her idea: "because if the Earth did not spin, we would always be the same".

The idea that the movement of the Sun is only apparent gains momentum. In the process of social interaction, students evolve to meanings that reveal different levels of conceptual development:

- Some evolve into a construction that combines the spontaneous idea of the Sun moving around the Earth with the idea of the Earth's rotation, conveyed in the social context of the class: "It's the Sun and the Earth"; "I think the Earth moves, but the Sun moves everywhere".
- Others, who were previously partial to the movement of the Sun, now show an understanding of the Earth's rotation as the cause of the apparent motion of the Sun, as in the cases of Sara and Mafalda: "it's the Earth"; "it's the Earth that is always spinning"; "the Earth is a ball and it's always spinning and it seems like it's the Sun that moves".
- There are also those who develop a conceptual formulation of a higher level than the previous, with the generalization of the Earth's rotation movement as a cause of the day and night alternation: "as the Earth moves slowly and we are here in our place, it seems that the Sun is moving. But it's not; it's the Earth (...) because if the Earth did not spin, we would always be the same".

G. *The Earth's rotation movement in the presence of the Sun: the day and night alternation*

G_1. The day and night alternation in Portugal in the Earth– Sun model. **Passage from the diary:**

> "If it's the Earth that rotates, what must we do for it to be nighttime in Portugal?" – I ask. Without hesitation, the children recognize the need to rotate the Earth globe: "we have to rotate the Earth" – some say; "we turn the Earth" – others; "we must rotate the Earth" (Rui; 6.6 years). I slowly rotate the globe and ask them what had happened. They say that now it is nighttime in Portugal. "And on the other side of

> the Earth, what is it now?" – I ask. "It's daytime" – the children answer. When asked about what they must do for it to be daytime in Portugal again, the children answer that "they must rotate the Earth".

When applied to the Earth – Sun (globe – flashlight) model, the comprehension that the Earth revolves around itself promotes the acknowledgement that the alternation between day and night is a consequence of the Earth's rotation movement.

G_2. Being daytime in Portugal, could there be night in our country if the Earth stopped spinning?

The question raises the level of reflection in the class, translating into more elaborate answers. The students understand that, for it to be night, the globe, i.e. the Earth, must keep spinning until Portugal is again on the non-illuminated part: "it cannot be. If the Sun were always in Portugal and the Earth didn't spin, it would always be daytime and there would be no night. If it were nighttime and it wasn't spinning, it would always be nighttime" (Sara); "there couldn't, it would always be daytime" (Gabriel); "it would always be the same" (Mafalda).

G_3. Generalization of the day and night alternation. **Passage from the diary:**

> "So, why is there day and night?" - I ask. Gabriel states: "because the Earth is always spinning. It never stops". Other children intervene: "because the Earth is always spinning" (Sara); "if it didn't spin, there would only be day" (Lionel); "it's the Earth that rotates, and then there is day and night" (Bruno); "if it were daytime and the Earth stopped, there would never be night again. If it were night, when the Earth stopped, there would be no more day" (Mafalda). Rui adds: "only if the Earth moved again". The children who did not answer agreed with those answers and apparently understood that the succession of day and night was a result of the Earth's rotation.

The students' thoughts about the succession of days and nights have focused on the globe, based on the concrete situation of Portugal. When they are asked why there is day and night, the answers point towards the generalization of the idea of the alternation of day and night as a consequence of the Earth's rotation movement: "because the Earth is always spinning. It never stops"; "it's the Earth that rotates, and then there is day and night"; "if it were daytime and the Earth stopped, there would never be night again. If it were night, when the Earth stopped, there would be no more day".

H. Alternation of day and night: the Sun as a cause vs. consequence of the Earth's rotation movement

H_1. Confrontation between the intuitive ideas and the newly acquired learning. **Passage from the diary:**

> At the beginning of the class the idea sprang up that, in the evening, the Sun would go "away" or that it "had gone to sleep". I remind them of those ideas and ask them what they have to say now. Sara begins by saying: "The Sun never sleeps, it never goes out, it never travels. It is always still, in one place." Other interventions follow: "It didn't go away" (Filipa; 6.2 years), "it's like a statue" (Gabriel; 6.3 years), "it never does anything, it is always still" (Lionel; 6.9 years); "it's as if it were glued to a wall" (Mafalda; 6.4 years). "If it didn't go away, then why don't we see it during the night?" – I ask. Sara answers again: "because the Earth is always rotating and the Sun stayed in the part where it was. It's on the other part" – says Mafalda, in the meantime. Júlia adds: "We are not the only ones who need the Sun, other people also need it. They also have plants to grow and they need the Sun"; "the Earth spins and then the other part gets the Sun and the part that had the Sun gets night" – says Joana (6.7 years).

This confrontation reveals remarkable progress in the comprehension of the apparent motion of the Sun. The conceptual level of development achieved by the students allows them a critical look at those ideas, and therefore the absence of motion of the Sun now makes more sense to them. The child who previously claimed that the Sun went to sleep at night is now the first to answer, in a critical tone: "The Sun never sleeps, it never goes out, it never travels. It is always still, in the same place". Other children now present solid arguments for the fact that we do not see the Sun during the night which rely on the Earth's rotation movement.

Analysis of the assessment results of the acquired learning

At the end of the class, students answered individually to a questionnaire with true or false items about the alternation of day and night. After three weeks, the students answered the same questionnaire. The following table shows the results obtained at the two moments.

Table 1. *Results Obtained in the Two Moments of Assessment of the Student Learning*

Items	Correct answers	
	M1 (%) after class	*M2 (%)* after 3 weeks
1. The Earth is round like a ball	16 (88.9%)	18 (100%)
2. The Sun stops shining during the night.	9 (50%)	10 (55.6%)
3. It is daytime in the part of the Earth that is facing the Sun.	14 (77.8%)	16 (88.9%)
4. When it is nighttime in Portugal, it is also nighttime in the whole world.	11 (61.1%)	14 (77.8%)
5. The Earth never stops spinning.	14 (77.8%)	14 (77.8%)
6. When it is daytime in Portugal, it is nighttime in other countries.	14 (77.8%)	16 (88.9%)
7. There is day and night because the Earth is always rotating.	12 (66.6%)	13 (72.2%)

These results suggest that the learning acquired by the students was meaningful because it is long-lasting, as opposed to memorized learning, which is soon forgotten (Coll & Martín, 2001).

Discussion

This study did not aim to assess the impact of Reflective Experimental Science Teaching (REST) on improving the understanding of the topics under study. However, the combination of the students' learning described in the class diary with the results obtained from the questionnaire suggests that the process of teaching and learning occurred in the classroom by means of the practice of REST may have had a highly positive effect on the students' learning. Thus, the combination of such data is indicative that the majority of students have developed a good learning about the Earth's shape and alternation day and night, as a result of the rotation of the Earth.

The construction of this learning started from the students' initial ideas, whose identification is an integral part of the teaching and learning process. Despite differences in method, it can be verified that ideas about the shape of the Earth are convergent with some ideas identified by other authors (Nussbaum, 1985; Vosniadou & Bewer, 1992) in children from other countries, cultures and similar age groups.

Through the interpretative content analysis of the class diary it is also possible to identify and characterize some of the processes that promote the quality of the students' thought and learning. The following stand out:

- the communication of ideas and ways of thinking to the class allows the students to contrast their own ways of thinking with the thoughts of others. In this process of verbalization, the students become more aware of their own ideas and the ideas of others. This increased awareness promotes, in some children, the need to restructure their ideas when confronted with other more plausible and consensual ones that appear in the social context of the class. Take, as an example, the communication to the class of the meanings implied in the drawings of the Earth;

- the discursive activity generated around the ideas that spring up in the classroom through the conjoint influence of their peers and the teacher's action improves the quality of those ideas, allows for the participation of other students and favors the development of more elaborate meanings;
- the students' more evolved meanings and the teacher's action direct and support the conjoint cognitive activity, allowing the slower students to elaborate new reconstructions and approximations to those meanings, which, after being verbalized in the social context of the class, are then shared by a growing number of students;
- the students' sociocognitive activity generated around experimental evidence introduces a considerable increase in the development of scientific meanings – the shape of the Earth; what is day and what is night; the alternation of day and night as a consequence of the Earth's rotation movement;
- the teacher's action, through continuous and recurrent reflective questioning (scaffolding), not only helps students to become aware and regulate their cognitive activity, but it also promotes their ability to escalate to progressively higher levels of cognition and learning;
- the introduction of significant and familiar analogies related to their day-to-day contexts facilitates the comprehension of particularly difficult situations, as was the case of the apparent motion of the Sun;
- the contrast between the learning acquired and their less evolved initial ideas triggers in the students a heightened awareness of their own learning – metacognitive knowledge;

The promotion of an experimental Science teaching practice in primary school has proved a difficult and complex task, as it requires that teachers assimilate and develop not only scientific knowledge, but also specific didactic knowledge about how to teach the subjects of specific curricular areas. The processes of teacher training, in our perspective, should be shaped by the practical and theoretical knowledge emerging from the holistic understanding of the teaching and learning processes, promoted and experienced in the classroom context. Thus, the present paper may prove a valuable resource for the initial and continuous teacher training process in order to endow these professionals with a specific knowledge on how to elicit and promote, within the classroom context, identical processes in approaching the curricular topic on the shape of the Earth and the alternation of day and night.

Finally, it can be argued that children are able to overcome complex cognitive challenges when they are approached in a collaborative context of stimulation and freedom of expression of their thoughts. Thus, the interaction with other more developed children, or with the teacher, and the domain of language promote higher levels of learning, which is an important factor for the development of thought (Vygotsky, 1978).

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