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# PUPILS' MENTAL MODELS OF EARTH'S INTERNAL STRUCTURE

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## Abstract

Mental models are fundamental for understanding the construction of knowledge and people' actions, constituting an important area in science education. In fact, Johnson-Laird (1983) argued that people think and reason with mental models, as it is impossible to directly understand the world. For this author, human mind construct internal representations, which are considered a bridge that connects people with the world. Mental models represent objects or specific situations, capturing its essential characteristics.

Although mental models are considered to be personal, incomplete, unstable and unscientific they allow pupils to understand and explain phenomena. As so, according to their experiences, pupils construct their own mental models, which are useful for their daily life. On the other hand, conceptual models are considered to be precise representations coherent with scientific knowledge that are introduced to them in the classroom. When pupils are confronted with conceptual models which are frequently different from their own mental models, restructuring processes may occur in diverse ways. Consequently, it is important that teachers become aware of the difficulty of this process and recognize the relevance of the diversity of their pupils' mental models, in order to promote activities that allow them to construct their models in an effective way. Pupils should have the opportunity to evaluate the importance of conceptual models and to correctly compare them with their previous knowledge. The present study aims to analyze how primary pupils imagine and represent the internal structure of the Earth. To attain this purpose, a questionnaire was constructed and validated by two university experts in primary education. The questionnaire asked pupils to draw the Earth's interior and to write an explanation of their own drawing intending to get an approximation of their Earth's internal structure mental models. One hundred and seventeen pupils of the last year of the primary school participated in this study. The sample had 58,1% of boys and 41,9% of girls, with ages ranging from 9 to 11 years old. The collected data was analyzed and mental models were classified into different categories: (i) Real Concentric Layers Model; (ii) Unreal Concentric Layers Model; (iii) Simple Random Structure Model; (iv) Complex Random Structure Model; (v) Fictional Model; (vi) Mixed Model; and (vii) External Model. Complex Random Structure Model was the model represented by the majority of pupils. In fact, only 35,9% of participants represent the Earth's internal structure divided into layers. Although pupils were allowed to represent movement with arrows, most of them possess a static mental model of the Earth.

Keywords: Mental models, Earth's internal structure model; Primary school pupils.

## 1 INTRODUCTION

Mental models are considered important for science education, as it is argued that people reason with mental models [1]. Mental models are considered internal representations of the world that endorse its understanding, as well as the capability to explain and predict [2]. Despite all the definitions found in the literature concerning mental models, Rook [3] advocated that a mental model is "a concentrated, personally constructed, internal conception, of external phenomena (historical, existing or projected), or experience, that affects how a person acts". In fact, a mental model is related to a specific topic and is subjective as it is a personal construct which attempts to fit over the realities of the world. Moreover, a mental model exists inside the individual's mind, affecting how an individual comprehends and acts.


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## 1.1 Mental Models

As it is impossible to directly understand the world, people mentally construct internal representations of it [2]. These internal representations are mental models that are constructed for people to act in and understand the surrounding world [4, 5, 6]. Mental models allow our mind to establish inferences and deductions which consequently allow us to explain and make predictions about the represented system [1, 5]. Mental models are then representative, coherent and functional to the person who builds it and are also incomplete and unstable, as they relate to the most relevant situations and some details of the model are forgotten or even discarded. They do not have well defined limits and they are unscientific and parsimonious. In fact, they are dynamic and flexible, as they change and improve with new relevant information [1, 5].

Johnson Laird, who played a major contribution in the development of the modern theory of mental models, argued that mental models are working models that allow individuals to understand and explain phenomena and to act in the world. For this author, this theory rests on three fundamental principles: (i) each mental model represents what is common to a distinct set of possibilities; (ii) mental models are iconic, as their structure as far as possible corresponds to the structure of what they represent; and (iii) mental models only represent what is true concerning the state of things that constitute them - principle of truth. People usually look for potentially truthful possibilities in order to successfully interact in the world [7].

For Johnson-Laird, there are three classes of mental representations: propositional representations, mental models and images. Propositional representations can be defined as strings of symbols similar to natural language, being these representations verbally expressed. Images, which are defined as views of models, are specific and detailed representations that preserve many aspects of certain objects or events, seen from a specific angle. As a consequence, mental models are analogue representations which do not contain specific aspects of a certain instance and may be seen from different angles. As an example, the situation “the board is on the wall”, might be mentally represented as a proposition (as it is verbally expressed); as a mental model (of any board in any wall); or as an image (of a certain board in a certain wall) [1, 2].

Johnson-Laird compares mental representations with the languages of computer programming, comparing mental models and images with high level languages and propositional representations with the machine languages (strings of 0 and 1) [1].

In Science Teaching it is important to distinguish mental models from conceptual models. In fact, while mental models are incomplete, unstable and unscientific conceptual models are precise and complete representations that are coherent with the scientifically accepted knowledge [1, 2]. Conceptual models are thus external representations that are created by scientists or teachers and may be used to facilitate the teaching and learning process.

However it is important that teachers become aware of the fact that pupils hold different mental models which are functional to them. Indeed, it is important that teachers diagnose and understand pupils’ mental models and that they develop materials and strategies that enhance pupils to develop appropriate mental models [1, 2].

## 1.2 Earth’s internal model

Regarding literature review, we can say that in the 70$^{th}$ decade research in science education was focused in misconceptions, in the 80$^{th}$ decade it was concerned with conceptual change and in the 90$^{th}$ decade it was devoted to mental models [2]. However and despite the direction of science education research, many studies were conducted focused in meaningful learning and cognitive development.

King [8] advocated that people of all ages hold incorrect views about the Earth and that the incorrectly embedded views may greatly inhibit geoscience understanding. Indeed, even teachers and science textbooks possess and contribute to the dissemination of various less consistent Earth’s science mental models or alternative conceptions. In fact, in a study conducted by Torres and collaborators [9] which aimed to evaluate Portuguese prospective science teachers’ views of Nature of Science and Earth’s structure model, some problems were detected regarding earth’s structure model topic, especially related to Mohorovičić discontinuity and to the representation of earth’s structure model.

Moreover, Dove [10] argued that the imprecise use of language as well as the abstract nature of the contents in Earth science may also play a major role in this process. As a consequence, it is important to understand pupils' mental models and to give attention to these matters in order to improve pupils' learning.

Vosniadou and Brewer [11] conducted a study with primary pupils and found that these pupils have difficulties in understanding Earth's shape. Beside the spherical model, it was possible to identify five alternative mental models of the Earth which are used by children consistently: the rectangular Earth; the disc Earth; the dual Earth; the hollow sphere and the flattened sphere. Concerning these models, rectangular Earth mental model refers to a flat rectangle shape Earth and disc Earth mental model to a flat and round Earth. The hollow sphere mental model consists of a spherical Earth where people live inside and the flattened sphere model consists of an Earth shaped like a thick pancake, round on the sides, but flat on the top and the bottom. Children with a dual Earth mental model believe in two earths: a flat earth where people live and a round earth which is up in the sky.

These alternative models of the Earth may be considered synthetic models, as they could be derived from a synthesis of the scientific information and an initial concept of pupils. In fact, children construct alternative models (hybrid models) about the Earth as they assimilate the scientific information to their prior knowledge under the influence of their native culture [1, 12].

Francek [13] organized and analysed over 500 geoscience misconceptions. These misconceptions, applied in this study to any belief which is contrary to current scientific understanding regarding the topic, where organized according to different subjects and to age categories. Concerning structure of the Earth subject, this author presented 32 misconceptions of many age groups. Relating to primary pupils, it was found that they do not differentiate the Earth into layers; that they assume that the Earth is composed of tarmac, bricks, skeletons, pipes, dead plants, 'old stuff', and centipedes; that they think that it is colder inside the Earth as the sun cannot reach it, that they presume that the densest layers on the Earth is found above the South Pole; and that the Earth has a magnet at its core.

In a study developed by Dove [10], some findings related to misconceptions about Earth's structure were also organized and described. In fact, in a study where pupils (with ages ranging from 11 to 15) were asked to draw a cross-section of the Earth, they represent a hot, melted centre from which magma flowed out to volcanos on the surface. When it comes to the temperature at the centre of the Earth, it was found that pupils (with ages ranging from 9 to 10) were divided as to whether the Earth was hotter or colder at the centre. In fact, some children proposed that the centre of the Earth is colder, as the sun's rays could not warm it. Some of them also suggested that the cold water in the sea reached the centre of the Earth and lowered its temperature.

As referred above, it is fundamental to understand pupils' previous knowledge, as the presence of erroneous previous knowledge may hinder understanding of Earth science concepts [14]. In fact, when conceptual models are introduced to pupils in class, they might: (i) interpret it in accordance with the knowledge they already have (generating hybrid models); (ii) only memorize the information to the test; or (iii) construct mental models coherent with conceptual mental models. The third possibility is the most difficult to achieve but also the one desired in science education classes. This difficulty is even stronger in Earth science classes, especially if the conceptual model is contradicted by intuitive knowledge derived from observations since early childhood [1, 14].

The use of models in science classes can be really useful to demonstrate phenomena and to explain sophisticated knowledge, especially in Earth science classes. However, the use of models in classroom should overtake the traditional way and should be used in an effective way so as to ensure the proper relationship between the model and the phenomenon [15, 16,17].

# 2 METHODOLOGY

This study aims to analyse how Portuguese primary pupils imagine and represent the internal structure of the Earth.

## 2.1 Instrument

To analyse pupils' mental models, a questionnaire was constructed and validated by two university experts in primary education. The questionnaire contained two tasks, where pupils were asked to draw the interior of the Earth and to explain their own drawing.

## 2.2 Sample

The sample comprised pupils that attended the last year of the primary school, in different schools in Lisboa, Portugal. One hundred and seventeen pupils, with ages ranging from 9 to 11 (mean= 9,45; S.D= 0,53) answered the questionnaire. The characterization of the sample is presented in table 1.

**Table 1 – Sample characteristics.**

| Gender | | Age Range | Future Profession | | Parents' education level | | |
|---|---|---|---|---|---|---|---|
| | | | | | | Father | Mother |
| | | | | | | | *School 1 (n = 35)* |
| Females | 15 (42,9%) | 9-11 | Science-related jobs | 1 (2,9%) | Primary Education | 4 (11,8%) | 5 (14,3%) |
| Males | 20 (57,1%) | | Non Science-related jobs | 34 (97,1%) | Basic Education | 10 (29,4%) | 12 (34,3%) |
| | | | Do not know | | Secondary Education | 17 (50,0%) | 14 (40,0%) |
| | | | | | University degree | 3 (8,8%) | 4 (11,4%) |
| | | | | | | | *School 2 (n = 67)* |
| Females | 28 (41,8%) | 9-11 | Science-related jobs | 7 (10,6%) | Primary Education | --- | --- |
| Males | 39 (58,2%) | | Non Science-related jobs | 56 (84,8%) | Basic Education | 1 (1,5%) | 1 (1,5%) |
| | | | Do not know | 3 (4,5%) | Secondary Education | 5 (7,6%) | 7 (10,6%) |
| | | | | | University degree | 60 (90,9%) | 58 (87,9%) |
| | | | | | | | *School 3 (n =15)* |
| Females | 6 (40,0%) | 9-10 | Science-related jobs | 2 (15,4%) | Primary Education | --- | 1 (6,7%) |
| Males | 9 (60,0%) | | Non Science-related jobs | 11 (84,6%) | Basic Education | 1 (7,1%) | --- |
| | | | Do not know | | Secondary Education | 5 (35,7%) | 4 (26,7%) |
| | | | | | University degree | 8 (57,1%) | 10 (66,7%) |
| | | | | | | | *Total (n=117)* |
| Females | 49 (41,9%) | 9-11 | Science-related jobs | 10 (8,8%) | Primary Education | 4 (3,5%) | 6 (5,2%) |
| Males | 68 (58,1%) | | Non Science-related jobs | 101 (88,6%) | Basic Education | 12 (10,5%) | 13 (11,2%) |
| | | | Do not know | 3 (2,6%) | Secondary Education | 27 (23,7%) | 25 (21,6%) |
| | | | | | University degree | 71 (62,3%) | 72 (62,1%) |

## 2.3 Procedure

A questionnaire was constructed based on relevant bibliography and validated by two university experts in primary education. The final version of the questionnaire was applied to one hundred and seventeen pupils during the last term of 2012/2013 school year.

The data collected was analysed by three members of the research team that identified seven categories of the Earth's internal structure mental models: (i) Real Concentric Layers Model (RCLM); (ii) Unreal Concentric Layers Model (UCLM); (iii) Simple Random Structure Model (SRSM); (iv) Complex Random Structure Model (CRSM); (v) Mixed Model (MM); (vi) External Model (EM); and (vii) Fictional Model (FM). Concentric Layers Models (CLM) refer to representations where the interior of the Earth was divided in at least three concentric layers. In RCLM, layers were correctly identified (at least two of them), while in UCLM layers have wrong denominations or were constituted by materials that do not correspond to scientifically accepted materials. In Random Structure Models (RSM), internal materials were randomly distributed. SRSM is constituted by one substance and CRSM by many substances (two or more). MM corresponds to a model that merges characteristics from CLM and RSM, as pupils drawing refers to a model but their explanation to the other. EM corresponds to a model that represents Earth's external structure and FM corresponds to a creative model which refers to an imaginary and wonderful world.

Pupils' mental models were classified by two members of the research team into different categories according to their drawings and explanations.

Univariate analysis was undertaken (chi square test) to investigate the influence of gender, age, professional aspirations, schools and parents' education level variables in primary pupils mental model of the interior of the Earth.

# 3 RESULTS

According to the categories defined, only 35,9% of pupils represented the interior of the Earth divided into layers and only 15,4% of pupils presented a model similar to the currently accepted Earth's interior model (RCLM). The majority of pupils (47%) represented the Earth in a way consistent with the Complex Random Structure Model - CRSM - (table 2).

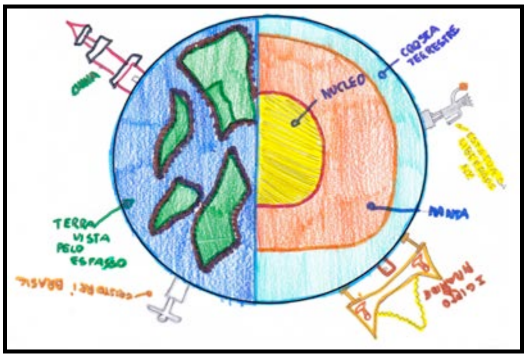
**Table 2 – Mental Models Categories and their frequencies.**

| Mental Model Categories | f | % |
|---|---|---|
| Real Concentric Layers Model (RCLM) | 18 | 15,4 |
| Unreal Concentric Layers Model (UCLM) | 24 | 20,5 |
| Simple Random Structure Model (SRSM) | 12 | 10,3 |
| Complex Random Structure Model (CRSM) | 55 | 47,0 |
| Mixed Model (MM) | 3 | 2,6 |
| External Model (EM) | 2 | 1,7 |
| Fictional Model (FM) | 3 | 2,6 |

**Legend:** f- frequency; % - percentage.

Examples of pupils' internal structure of the Earth mental models (drawing and description) are provided below (Fig. 1).

*"I drew the earth's core seen from above (…). I represented the core in yellow, the mantle in orange and the earth's crust in blue. (…)"*




Real Concentric Layers Model (RCLM)

*"Brown part is the soil; dark part is the hot rock that is between the soil and the lava. The red part is the lava that warms the rock and constitutes the innermost part of the earth."*

Unreal Concentric Layers Model (UCLM)

*"My parents explained to me that earth's core is only lava"*

Simple Random Structure Model (SRSM)

*"There are rocks, a crystal, a worm and soil in my drawing"*

Complex Random Structure Model (CRSM)

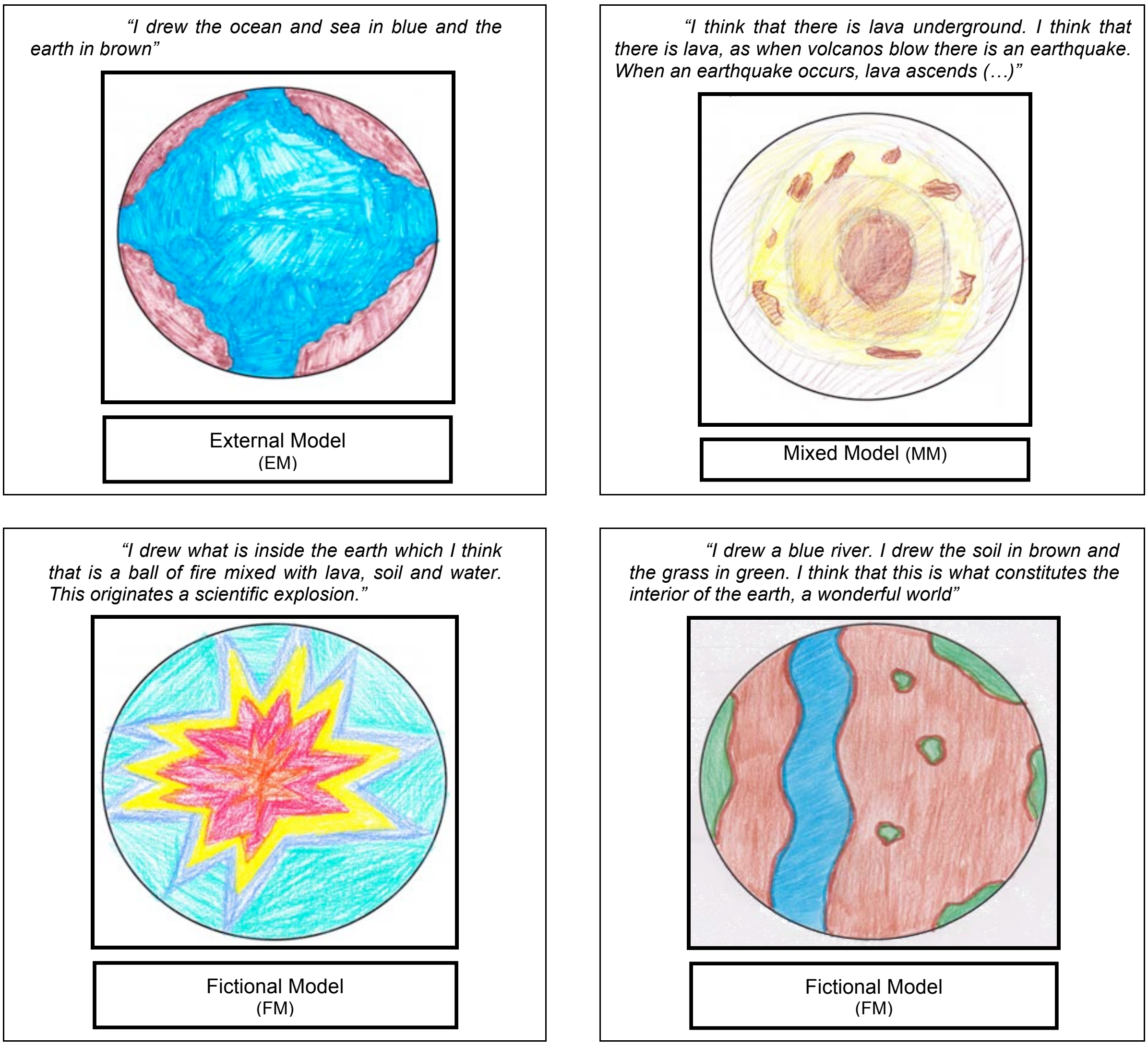



**Fig. 1**. Examples of pupils' drawings and its descriptions of the internal structure of the Earth.

Although pupils were allowed to represent movements with arrows, only 2,6% of them draw arrows or lines to represent Earth's dynamic (Fig.2). Moreover, a total of 10,2% of respondents made references to Earth's dynamic in their drawing's description or in their drawing.

Most of them focused in earthquakes which were originated by the nucleus core:

> *"It is the Earth's core that causes earthquakes, tsunamis and vibrations." (P20)*

> *"The innermost layer, which I do not know very much, is the core. When this layer shakes it may cause many events like earthquakes; tornados and tsunamis (…)" (P17).*

Only 1 pupil made some references to tectonic plates:

> *"I drew the tectonic plates as my father told me that earthquakes occur as a consequence of a collision between tectonic plates." (P12)*

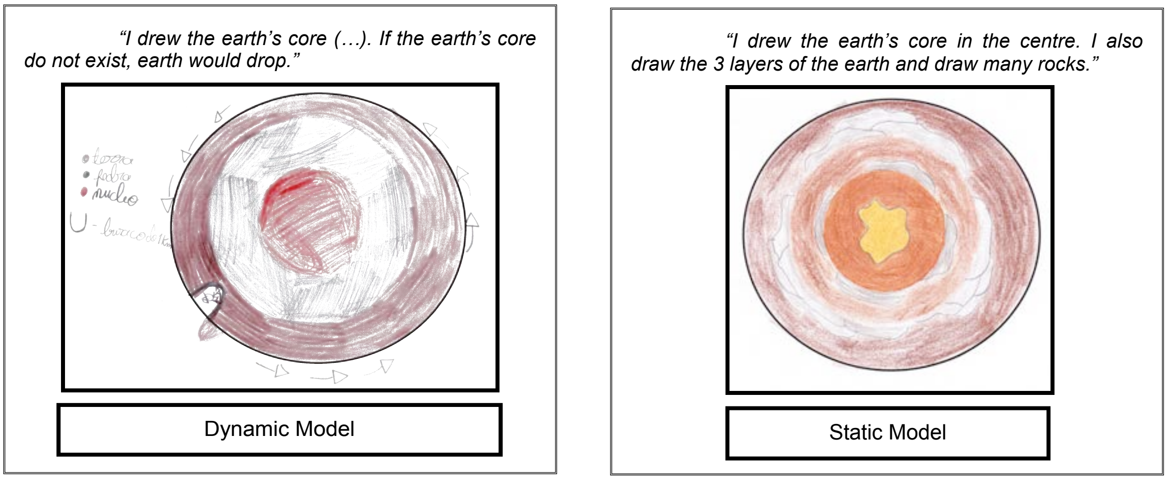



**Fig. 2**. Examples of pupils' dynamic and static drawings of the internal structure of the Earth.

In order to investigate the influence of gender, age, professional aspirations, school, and parents' education level variables in pupils' mental model, an univariate analysis was undertaken. Regarding pupils' frequency of correct mental models and gender, age and future profession variables there weren't found any significant differences between pupils – table 3.

**Table 3 – Univariate analysis of pupils' mental models with different variables**
(gender, age, future profession, school and parents' education level).

Frequencies of Correct Mental Models

| Variables | | | | | Univariate analyses | | |
|---|---|---|---|---|---|---|---|
| **Gender** | **Female** | | **Male** | | **TI** | **$\chi 2$** | **p** |
| | 7 (14,3%) | | 11 (16,2%) | | 18 | 0,078 | 0,780 |
| **Age** | **9 years old** | **10 years old** | **11 years old** | | **TI** | **$\chi 2$** | **p** |
| | 7 (10,6%) | 11 (22,4%) | 0 | | 18 | 3,4 | 0,183 |
| **Future Profession** | **Science-related jobs** | | **Non Science-related jobs** | | **TI** | **$\chi 2$** | **p** |
| | 2 (20%) | | 16 (15,8%) | | 18 | 0,696 | 0,706 |
| **Schools** | **School 1** | **School 2** | **School 3** | | **TI** | **$\chi 2$** | **p** |
| | 15 (42,9%) | 3 (4,5%) | 0 | | 18 | 29,142 | 0,000* |
| **Mother's Education Level** | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **TI** | **$\chi 2$** | **p** |
| | 0 | 6 (46,1%) | 8 (32,0%) | 4 (5,6%) | 18 | 21,041 | 0,000* |
| **Father's Education Level** | **Level 1** | **Level 2** | **Level 3** | **Level 4** | **TI** | **$\chi 2$** | **P** |
| | 1 (25%) | 3 (25%) | 10 (37%) | 3 (4,2%) | 18 | 18,090 | 0,000* |

**Legend:** Level 1 – Primary Education; Level 2 - Basic Education; Level 3 - Secondary Education; Level 4 – University degree; TI – Total; $\chi 2$- chi-square; p- p value; p* - p < 0,01.

However, when it comes to school variable, pupils of school 1 presented a better knowledge of the internal structure of the Earth, as 42,9% of the pupils of this school represented the currently accepted model (RCLM). This difference is statistically significant (p value < 0,001).

In relation to parents' education level, there was also a statistically significant difference between pupils (p < 0,01). Pupils whose parents hold basic or secondary education represented the currently accepted model more frequently.

## 4 CONCLUSIONS

With the results obtained we may conclude that primary pupils globally hold wrong mental models of the Earth's internal structure. The majority of them do not represented the Earth divided into layers, as 57,3% of pupils implicitly presumed that earth's internal materials were randomly distributed in Earth's interior.

The majority possesses a static mental model of the Earth, failing in recognizing the Earth's activity.

In general terms, we may assume that gender and age do not interfere with the accuracy of pupils' mental models about the Earth. Their future career aspirations also do not seem to interfere with their mental models. There were only statistically significant differences in the frequencies of correct mental models regarding parents' level education and school variables, which revealed that these variables are related.

It is important that teachers understand the diversity and particularities of pupils' mental models in order to implement efficient instruments and strategies for pupils to develop mental models coherent with currently accepted conceptual models.

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