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PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAÍSO

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Mental Models of the Earth's Internal Structure in Primary and Middle School Students in Chile

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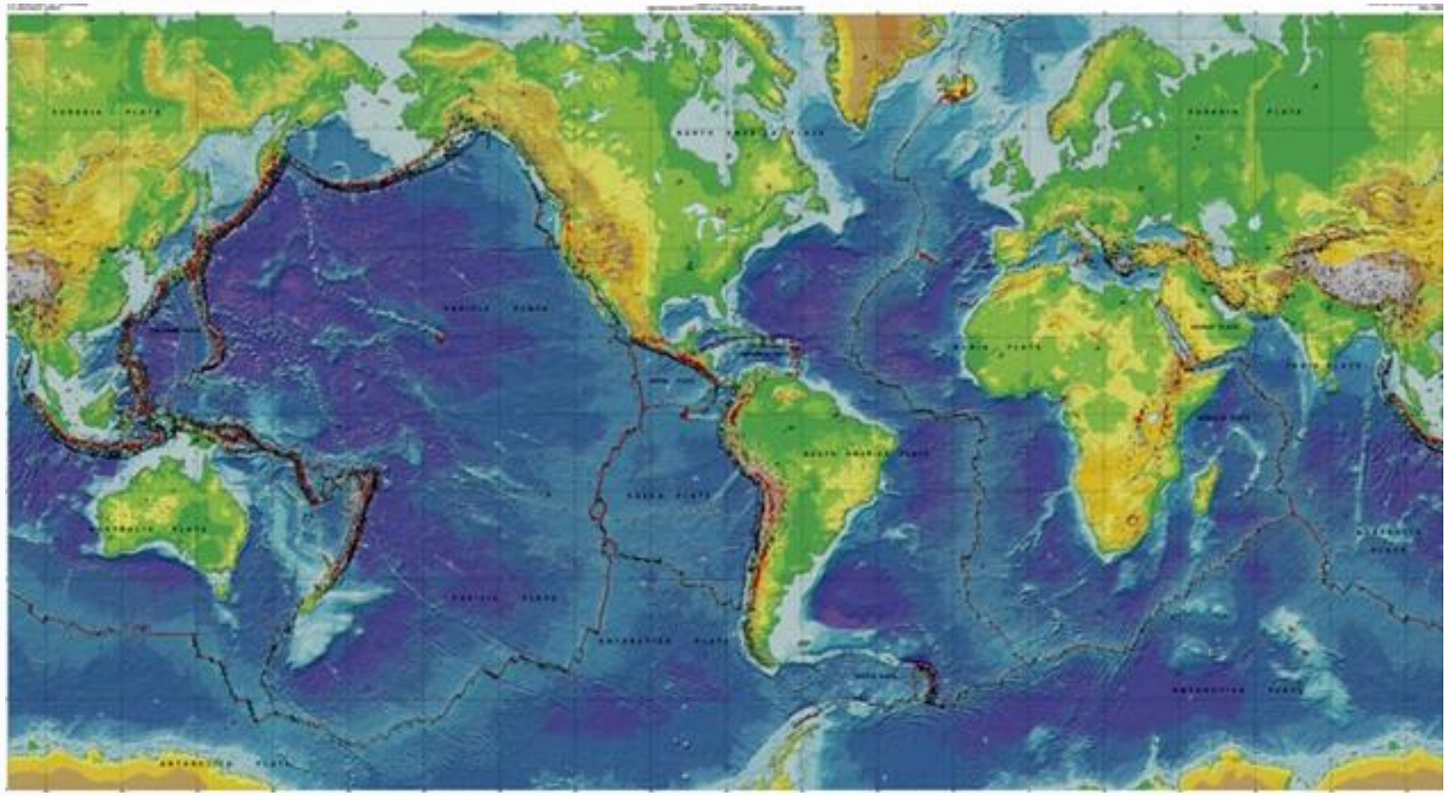
Introduction

Chile has an exceptionally pressing interest in educating its citizens about the scale and cause of the **geological hazards affecting population.** To do this, it is necessary for its inhabitants to **understand and know** what our planet is like and how it is formed, and therefore **how the Earth's dynamics** are. This will allow for having literate citizens who can make **responsible decisions** and thus be better prepared to live on an active plate margin.



Mental models are internal representations or conceptions that students construct as they make sense of their everyday interactions with the natural world.

- There exist **many alternative conceptions** about Earth's processes among students of all ages, from primary to secondary education (King, 2000, 2008).
- Elementary school students' representations of Earth's internal structure are often simplified and based on erroneous or incomplete concepts.

Science textbooks: conceptual errors have been detected

▲ Buscó un mapa del mundo donde aparecían las placas tectónicas y las recortó.

▲ Armó el mapa sobre una cubeta con agua y deslizó los fragmentos suavemente.

Why is this study relevant?

- We can better understand the mental models or alternative conceptions that students have regarding these concepts.
- We can reorient our teaching toward achieving conceptual change and deeper understanding.

According to Vosniadou et al. (2008) many of these alternative conceptions are synthetic models "formed as learners assimilate the scientific information to an existing but incompatible knowledge base without metaconceptual awareness".

Context

The current Chilean curriculum included this content in elementary (4th grade) and middle (7th grade) education and aims students to recognize and identify the Earth's layers.

[Ciencias de la Tierra y el Universo]

Objetivo de aprendizaje CN04 OA 15 Basal CN04 OA 15

Describir, por medio de modelos, que la Tierra tiene una estructura de capas (corteza, manto y núcleo) con características distintivas en cuanto a su composición, rigidez y temperatura.

Describe through models that the Earth has a layered structure (crust, mantle, and core), with distinctive characteristics in terms of composition, rigidity, and temperature.

Objetivo de aprendizaje CN07 OA 09 Basal CN07 OA 09

Explicar, con el modelo de la tectónica de placas, los patrones de distribución de la actividad geológica (volcanes y sismos), los tipos de interacción entre las placas (convergente, divergente y transformante) y su importancia en la teoría de la deriva continental.

Explain, using the plate tectonics model, the distribution patterns of geological activity (volcanoes and earthquakes), the types of interaction between plates (convergent, divergent and transform) and their importance in the theory of continental drift.

Research Question

The purpose of this study is to characterize the mental models that elementary and middle school students have about what the Earth is like inside and where they believe magma is located.

How are the mental models of Chilean primary and middle school students about the Earth's internal structure and location of magma?

Methodology

This is a descriptive study that seeks to analyze students' drawings in detail to determine their mental models of the Earth's internal structure and to recognize where students locate the magma.

Students

653 students from de 4th° to 7th grade/ six school from Santiago and Valparaiso (83 - 4th, 154 – 5th, 195 – 6th, 221 – 7th).

Instrument

Instrument on knowledge in Earth sciences previously validated, whose first question explicitly asks them to draw the layers of the Earth and indicate the location of the mantle (Vergara et al., 2020).

Validation

For the analysis of the drawings, we developed a rubric based on the work of Vosniadou et al. (2004, 2008) and Capps et al. (2013), which allows for the identification of the different models that students have about what the layers of the Earth are, how they are located, and where students locate Magma on Earth. For the location of the earth layers, 7 mental models were recognized, from the most sophisticated to the least scientific (A to G). For the location of the magma, 4 mental models were recognized from the most correct to the least correct (3 to 0). This rubric was validated by three researchers in science education working in Earth sciences and a geologist.

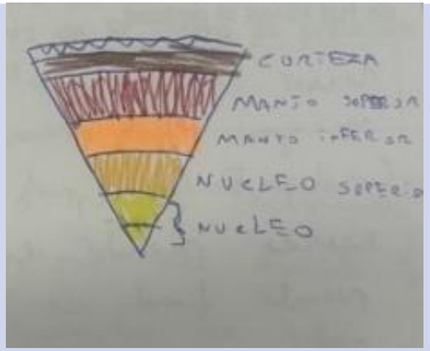
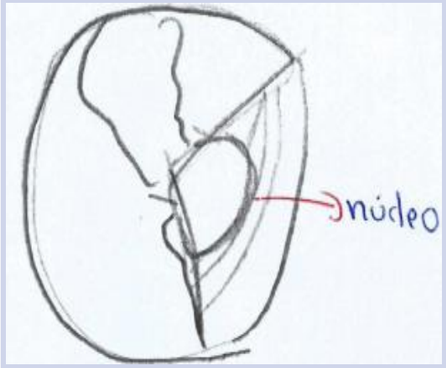
Analysis

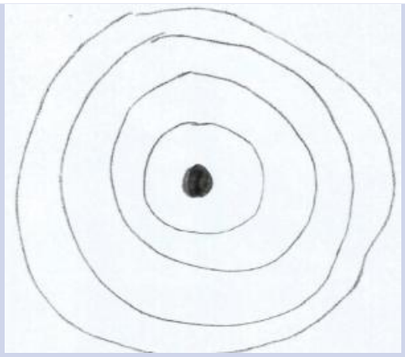
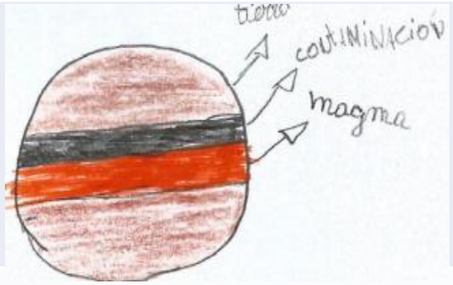
Each drawing was analyzed with the rubric by two researchers independently, and the differences in the coding’s were settled by a third researcher with Kappa 0.85, $p<0.05$ for first question and Kappa 0.88, $p<0.05$ for the second..

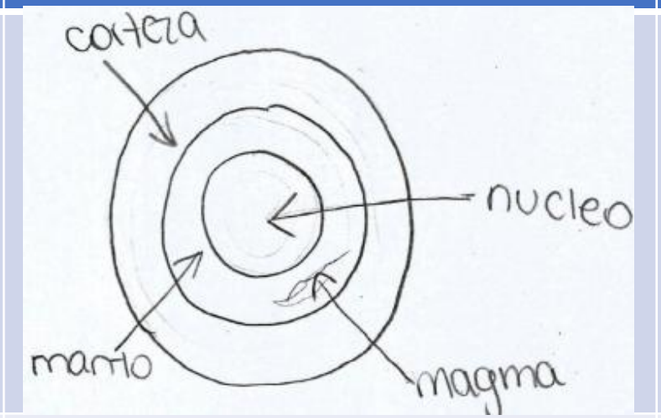
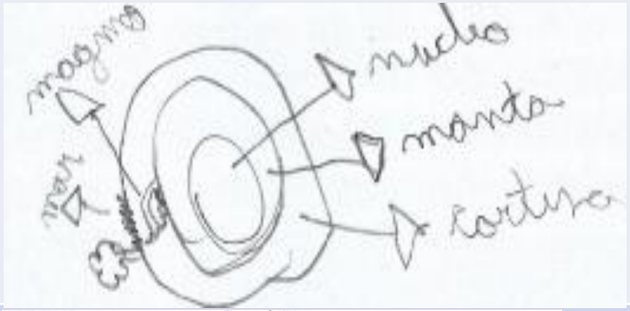
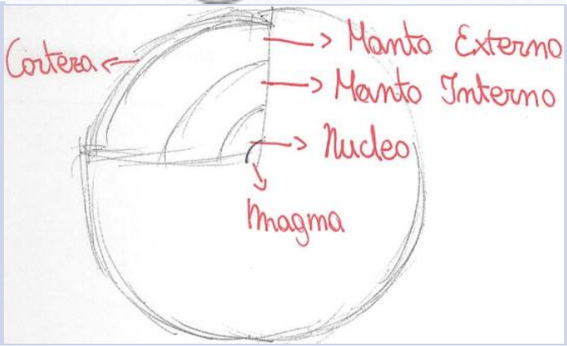
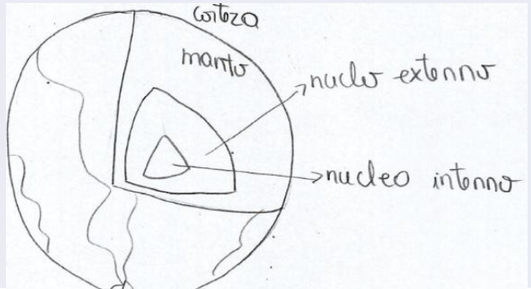
Methodology

Rubric of Layers’ Models and composition of the earth was based on Vosniadou et al. (2008)

The developed rubric allowed the students' drawings to be classified into seven mental models (A-G), from the most sophisticated and scientifically correct (A) to the least scientific (G).

CATEGORY DESCRIPCION	DRAWING EXAMPLE	COGIG
Draw the concentric layers within a spherical structure. Draw the layers in proportion to their density (thinner crust). Indicate the order and correct name. Core (inner-outer) - mantle - crust.		A
Draws the concentric layers, within a spherical structure. Does not draw them proportionally (no thinner crust). Does not differentiate between inner core and outer core. Identify core - mantle – crust.		B
Draws the concentric layers, within a spherical structure. Does not draw them proportionally (no thinner crust).Does not differentiate between inner core and outer core (confuses some of the names of these layers or does not include at most 1 of the corresponding layers). Only identifies 1 layer correctly.		C

CATEGORY DESCRIPCION	DRAWING EXAMPLE	COGIG
Draws the layers concentrically, within a spherical structure. Does not draw them proportionally (no thinner crust). Does not identify any layers.		D
Fictions models (Unreal). Draws a spherical structure, but with structures inside that do not correspond to reality.		E
Draw a concentric structure with structures outside (buildings) or continents.		F
Non-concentric layers.		G

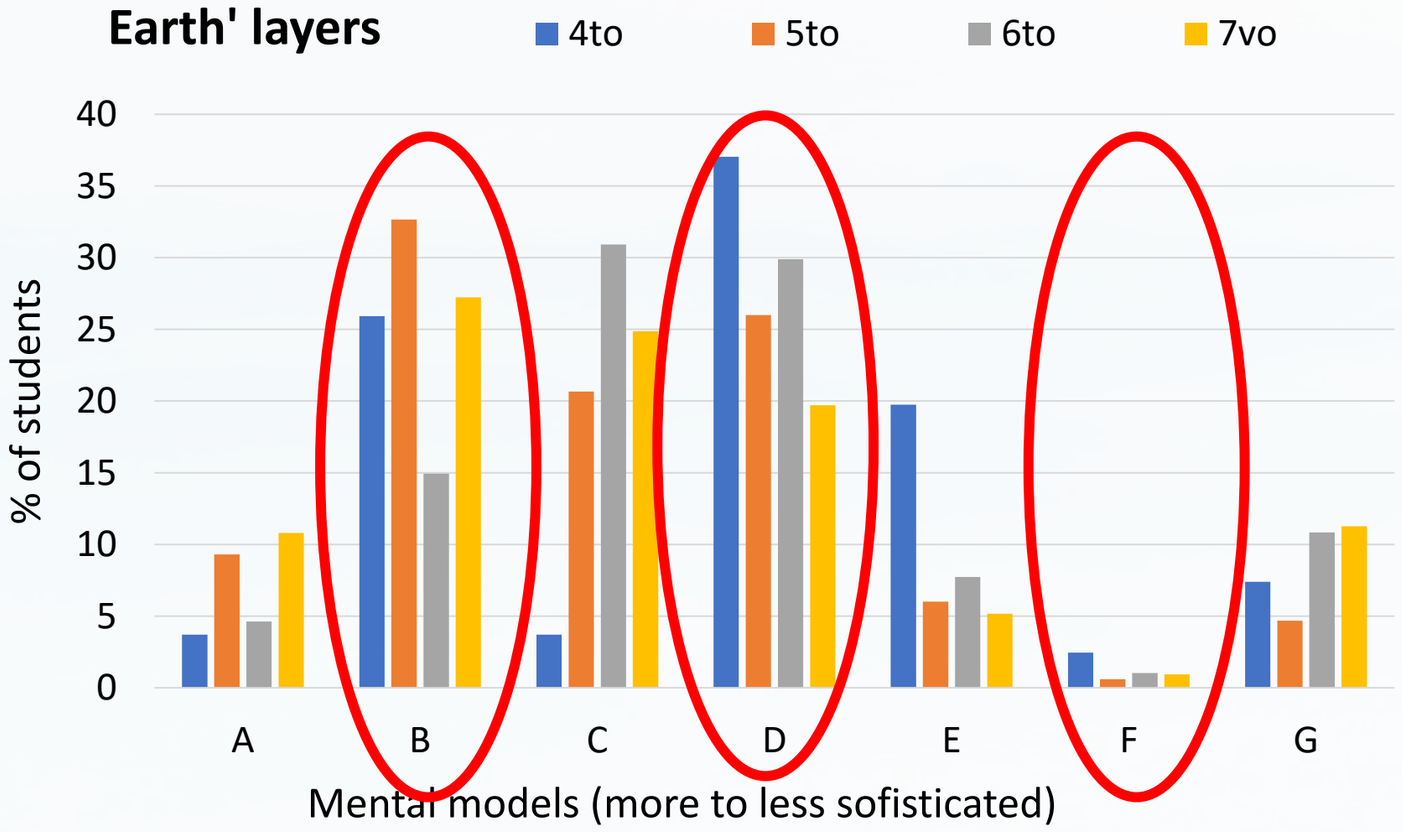
MAGMA LOCATION DESCRIPTION	DRAWING EXAMPLE	CODIG
Locate the magma in the mantle.		3
Locate the magma in the crust.		2
Locate the magma in the core or in the center.		1
No location of magma.		0

Rubric location of magma in the Drawings

To analyze the location of magma in students' drawings, a rubric with four categories was developed. The scientifically correct location of magma is in the mantle (code 3), while locating it in the Earth's core or center (code 1) represents a common but incorrect alternative conception.

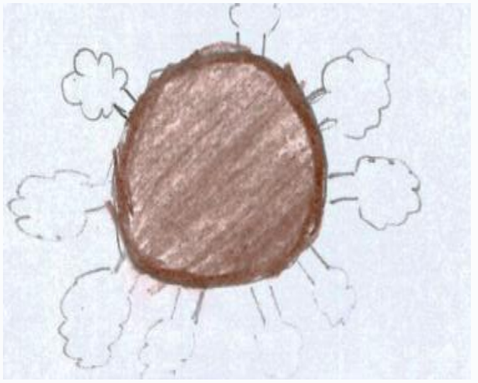
Findings: Mental Models of the Earth's Internal Structure

Analysis of the drawings shows a very similar pattern across all four grades. The most common mental models are those between B and D, that is, concentric layers of the same thickness that vary in the precision of their names. Fifth-grade students appear to have more sophisticated mental models (B), possibly because this content is taught at the end of fourth grade.



D

B

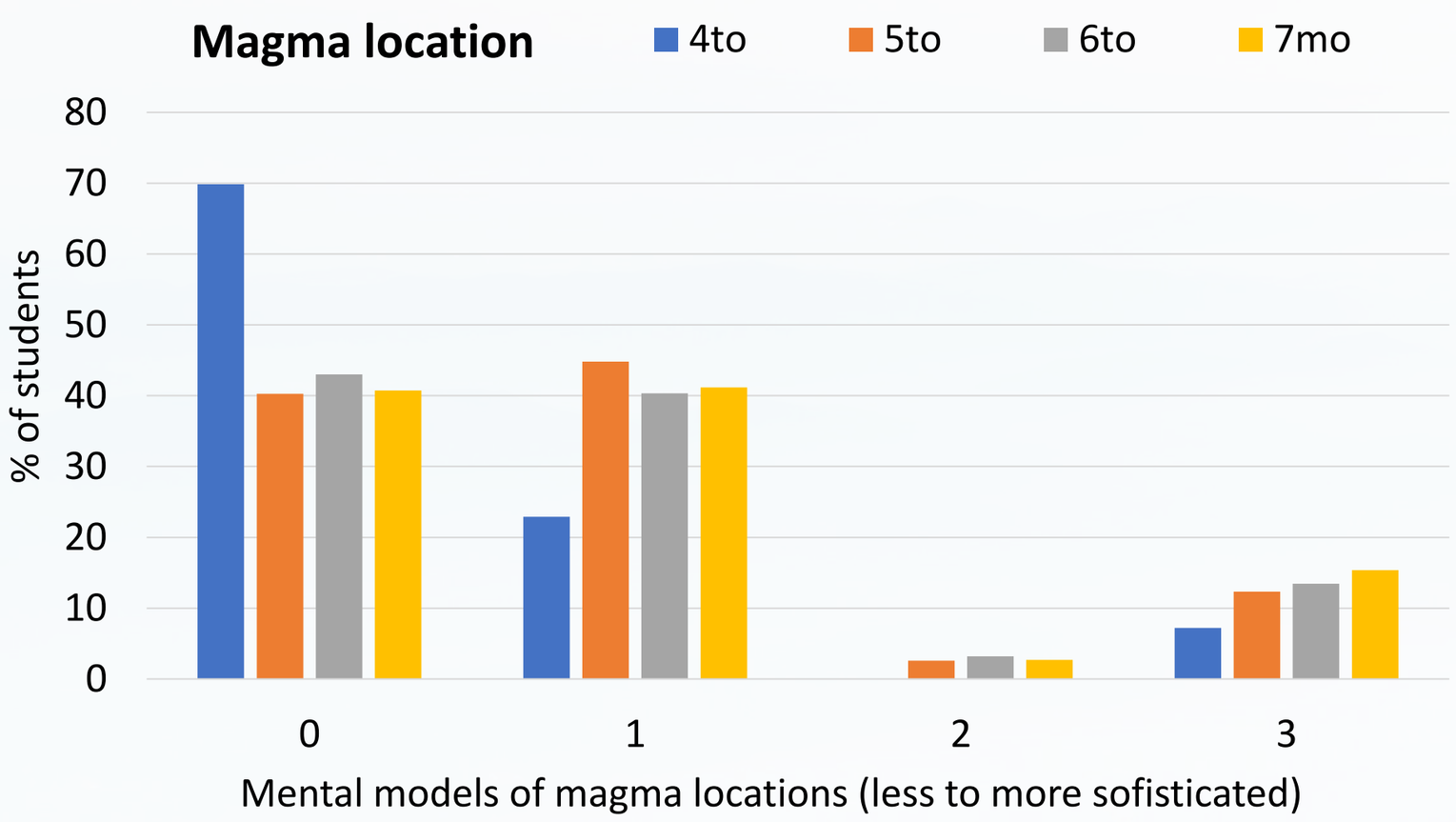


F

Figure 1. Percentage of students in each mental models of layers of Earth by grades.

Findings: Mental Models of magma locations

Regarding models of magma location, there isn't much difference between grades. All levels present many students with drawings that don't place magma in its scientifically correct location, with the majority placing it in the Earth's core or center.



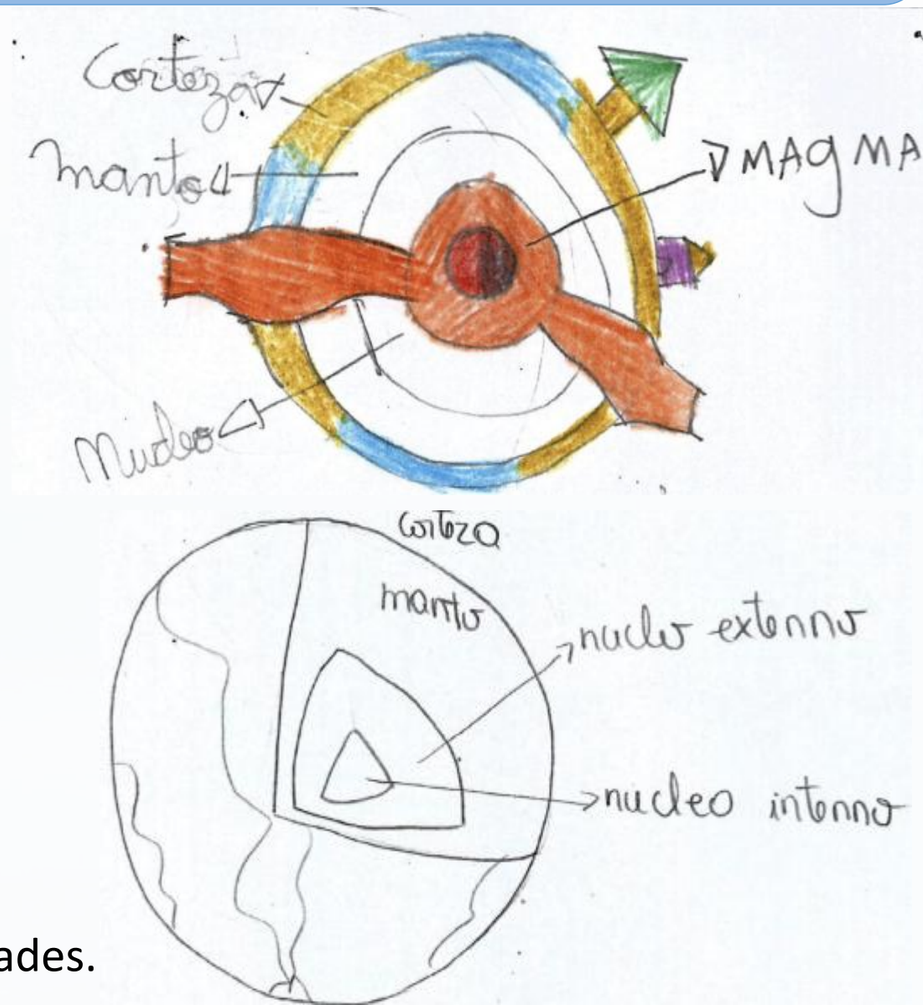


Figure 2. Percentage of students in each mental models of magma locations by grades.

Discussion and conclusions

- Despite living in a country with high geological risk, the mental representations of the Chilean students analyzed are similar to those found in other international studies (Vosniadou et al., 2008).

- This suggests that direct experience with geological phenomena does not necessarily lead to better conceptual understanding without explicit and effective teaching.

- These do not change drastically among students of different grades, from elementary to middle school, presenting the mental model of concentric layers with the magma in the center as the most common representation within the whole group.

Contributions and futures implications

- A validated rubric can be used by other studies.
- This study challenges the development of activities that aim at conceptual change, and work on the weak points.
- Use the rubric on drawings developed by students before and after the implementation of strategies that aim at conceptual change.

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