EUROPEAN SCIENCE EDUCATION RESEARCH ASSOCIATION

ESERA 2025 Copenhagen

Mental Models of the Earth's Internal Dynamics in Chilean Students: implementation with strategies for Teaching Earth Science

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FONDECYT N°1231783
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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 the population.**

It is essential for its inhabitants to understand what our planet is like, how it is formed, and, therefore, how the **Earth's dynamics work**.

This will help create scientifically literate citizens who can make **responsible decisions** and be better prepared to live on an active plate margin.

Mental Models

Are understood as internal representations that people build to describe, explain and predict real-world phenomena (Johnson-Laird, 1983).

They are developed from experience, prior knowledge, and interaction with the environment, and guide reasoning and decision-making, thus influencing a person's behavior (Johnson-Laird & Ragni, 2024).

They reflect the internal construction of intuitive and scientific knowledge that merges into synthetic or fragmented schemes, as described by Vosniadou and Brewer (1992).

In the context of Science Education, mental models help to understand how students interpret abstract concepts, such as the internal structure of the Earth.

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Alternative conceptions

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 internal structure are often simplified and based on missconceptions or incomplete concepts.

Different studies have used this tool to assess the understanding of scientific concepts in primary students to university, showing different levels of conceptualization and complexity in the visual representations generated.

(Alonqueo et al., 2015; Cabello, 2021; Cabello et al., 2022; Chang et al., 2020; Cardoso et al., 2018; Davis & Cabello, 2024; Fernández et al., 2012; Gobert, 2000; Greca & Moreira, 2000; Mclure et al., 2021; Park, 2014; Reiss & Tunnicliffe, 2001; Rodriguez & Moreira, 1999; Steer et al., 2005; Torres et al., 2013; Vosniadou & Brewer, 1992).

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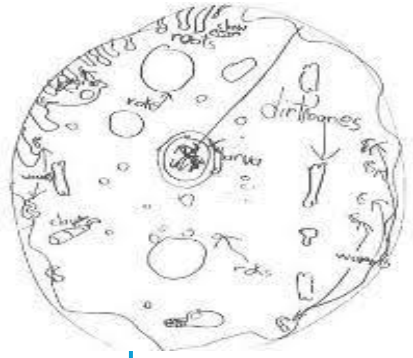

Why is this study relevant?

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”.

Chilean Context

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

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.**

Analyze, using models, **natural or human-caused risks in their local context (such as avalanches, fires, high-magnitude earthquakes, volcanic eruptions, tsunamis**, and floods, among others) and assess existing school and community capacities for prevention, mitigation, and adaptation to their consequences.

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Research Question

How do mental representations about the Earth's internal dynamics change in Chilean students in 4th , 7th, and 11th grade after a teaching sequence with strategies for teaching Earth Science?

Methodology

Cuantitative study – cuasi experimental design, with pre and post test type, without control group.

Students

267 students from of 4 th to 11 th grade / six school from Santiago and Valparaiso (51 - 4 th, 172 – 7 th, 44 – 11 th).

Instrument

Instrument on knowledge in Earth Science 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).

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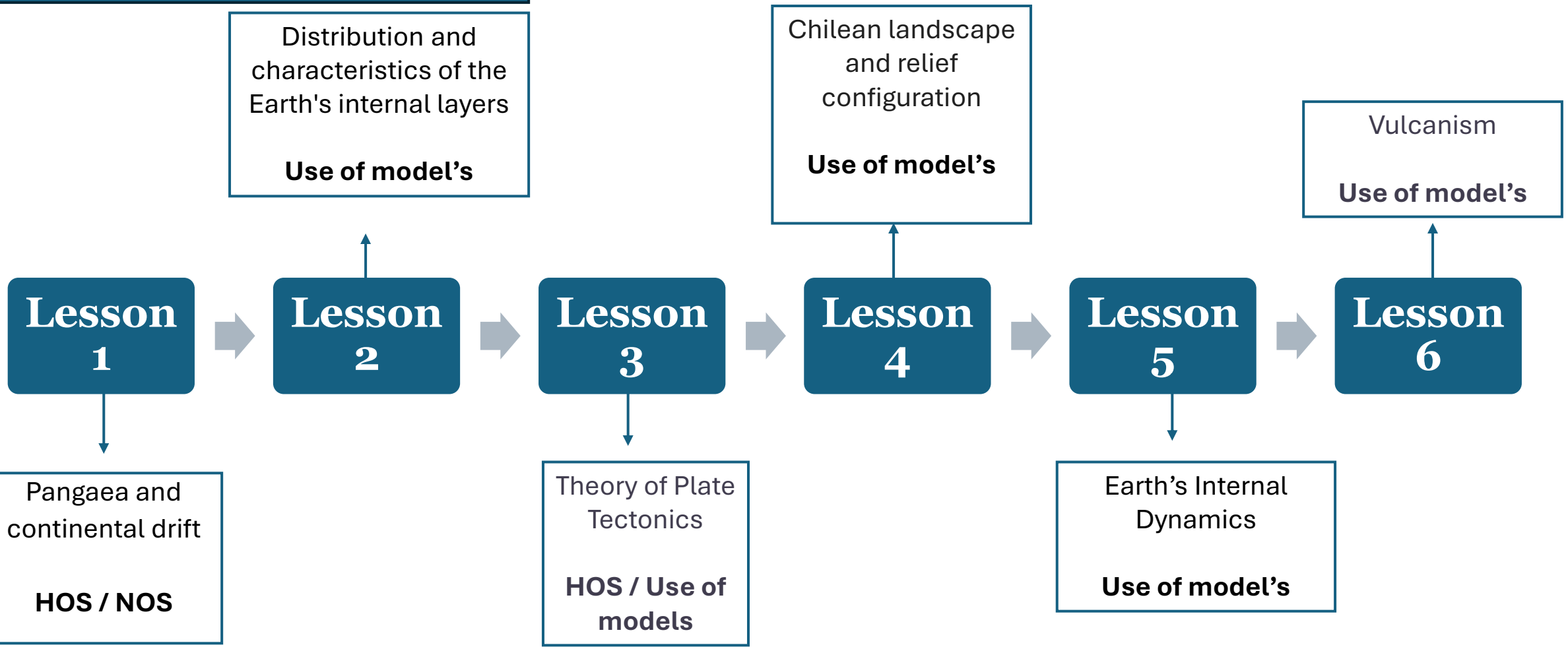
Teaching Sequence

Each lesson was from 90 min.



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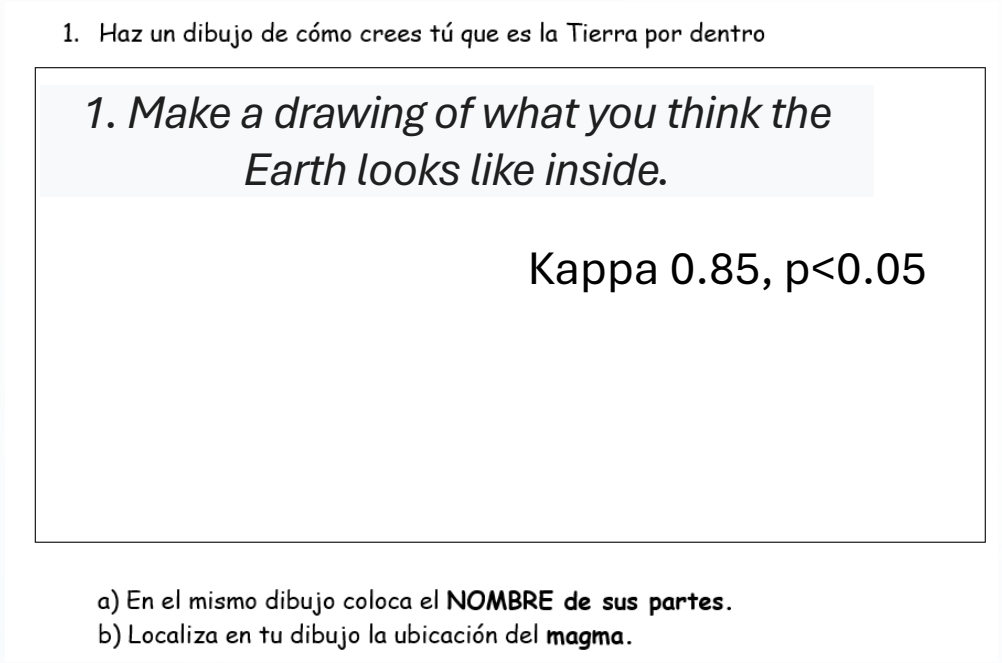
Methodology

Analysis of the drawings

We used a validated rubric based on the work of Vosniadou et al. (2004, 2008) and Capps et al. (2013) (Vergara et al., 2024), 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 in the Earth. Each drawing was analyzed by two researchers independently, and the differences in the coding's were settled by a third researcher.

To evaluate significant changes between mental models the following were performed:
- Analyze the normality of the data (Kolmogorov-Smirnov / Shapiro-Wilk)
- Nonparametric analysis to compare related samples, using the Wilcoxon test.

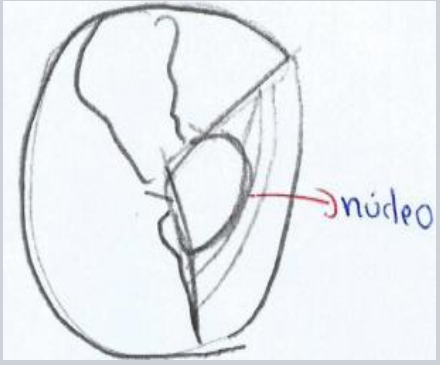


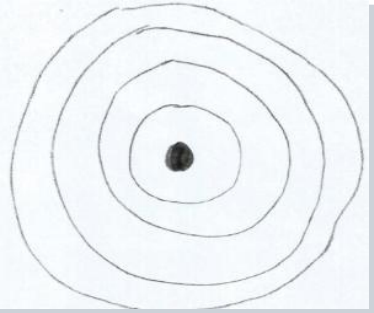
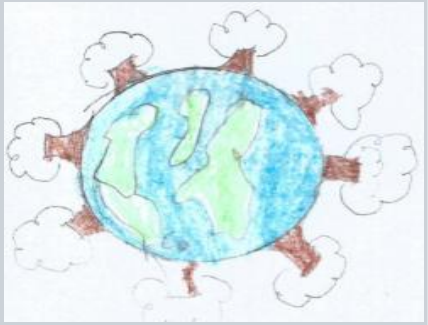
1. Make a drawing of what you think the Earth looks like inside.

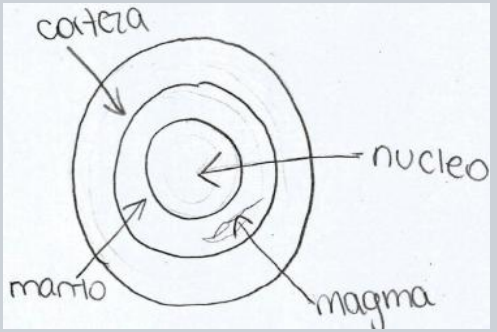
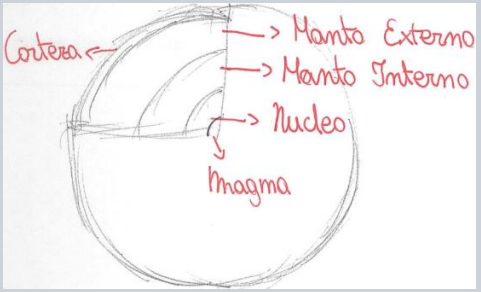
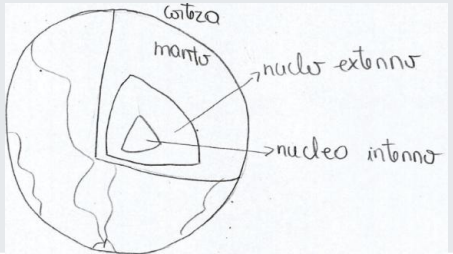
Kappa 0.85, p<0.05

a) In the same drawing put the name
b) Locate the location of the magma in your drawing

Kappa 0.88, p<0.05

CATEGORY DESCRIPCION	DRAWING EXAMPLE	CODE
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.		7
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.		6
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.		5

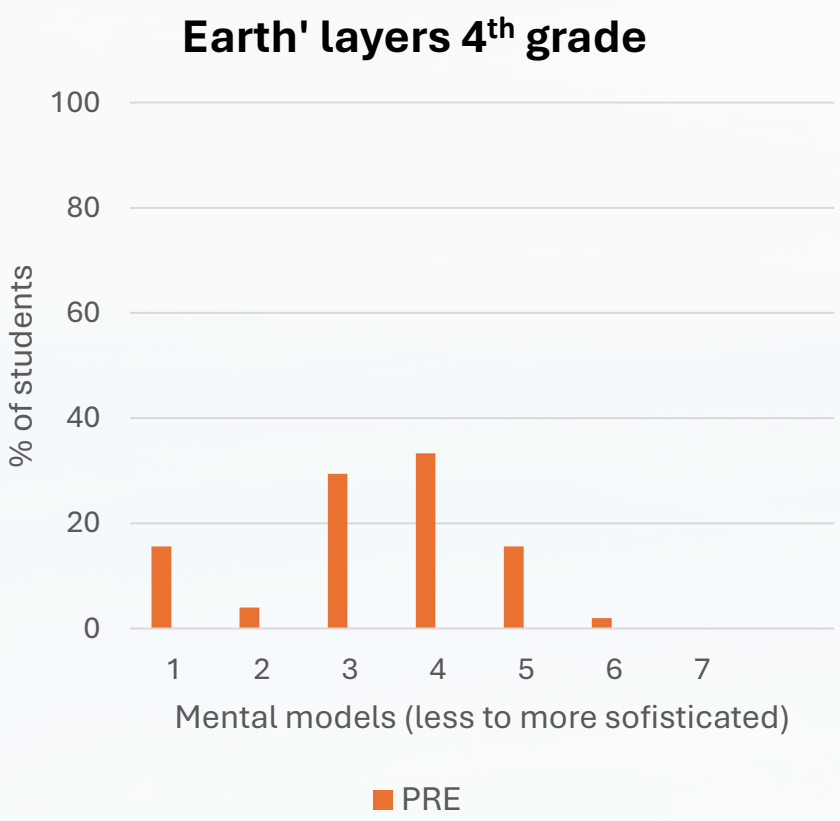
CATEGORY DESCRIPCION	DRAWING EXAMPLE	CODE
Draws the layers concentrically, within a spherical structure. Does not draw them proportionally (no thinner crust). Does not identify any layers.		4
Fictions models (Unreal). Draws a spherical structure, but with structures inside that do not correspond to reality.		3
Draw a concentric structure with structures outside (buildings) or continents.		2
Non-concentric layers.		1

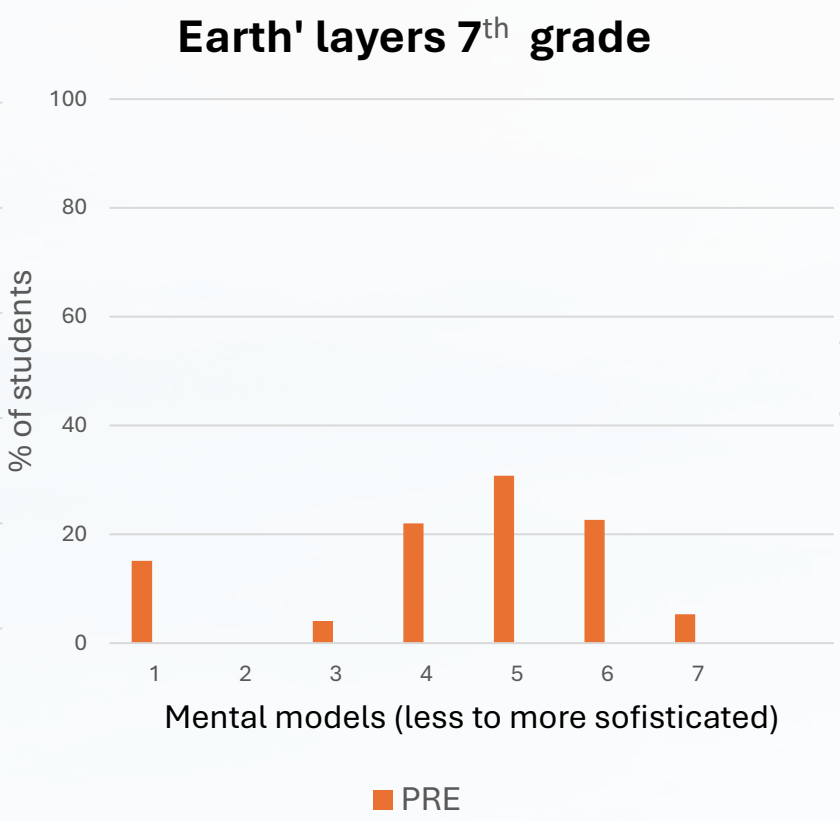
MAGMA LOCATION DESCRIPTION	DRAWING EXAMPLE	CODE
Locate the magma in the **mantle.**		**3**
Locate the magma in the **crust.**		**2**
Locate the magma in the **core** or in the **center.**		**1**
No location of magma.		**0**

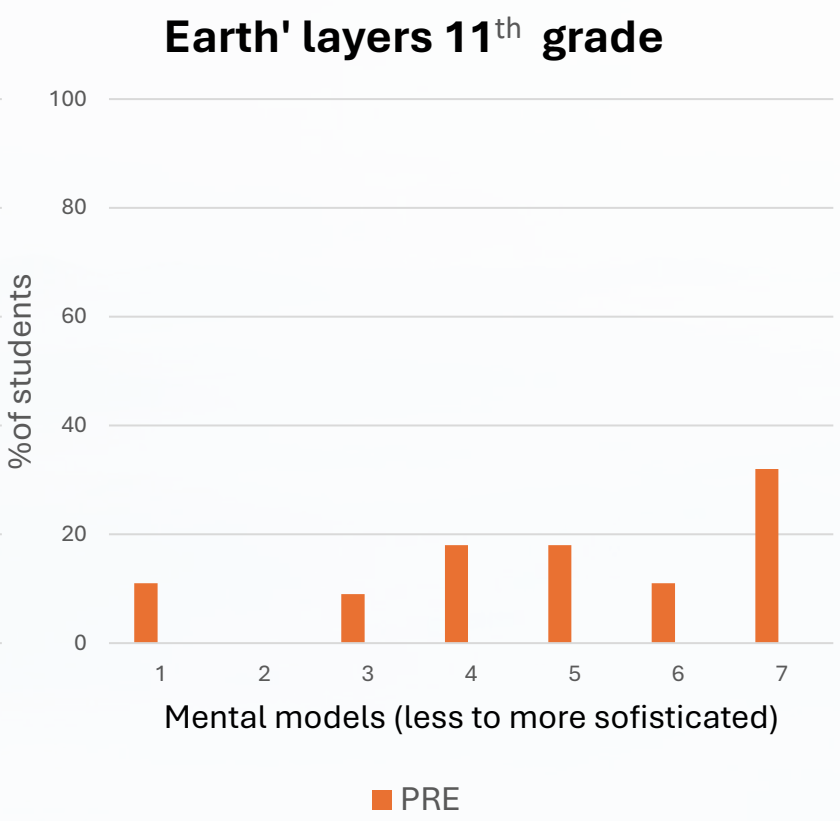
Rubric location of magma in the Drawings

To analyze the location of magma in students' drawings, a rubric with four categories was use.
Code 3 (more sofisticated), the correct location of magma in the mantle.
Code 1 (less sofisticated), locating the magma in the Earth's core or center, that presents a common but incorrect alternative conception .

Results: Earths internal structure PRE





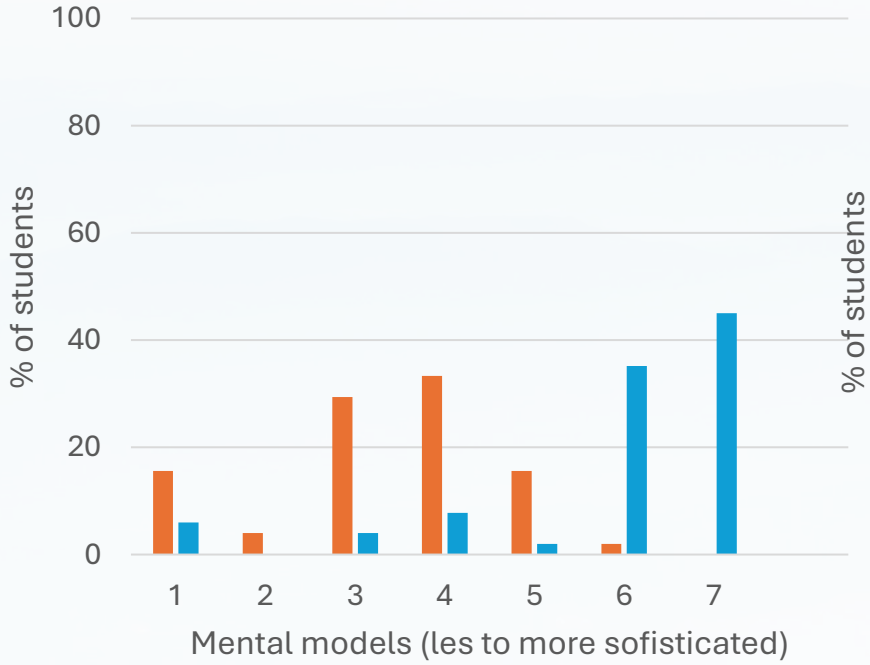


Results: Earth‘s internal structure PRE-POST

The pre and post test comparative analyses showed significant differences in two of the grades analyzed: 4th and 11th .

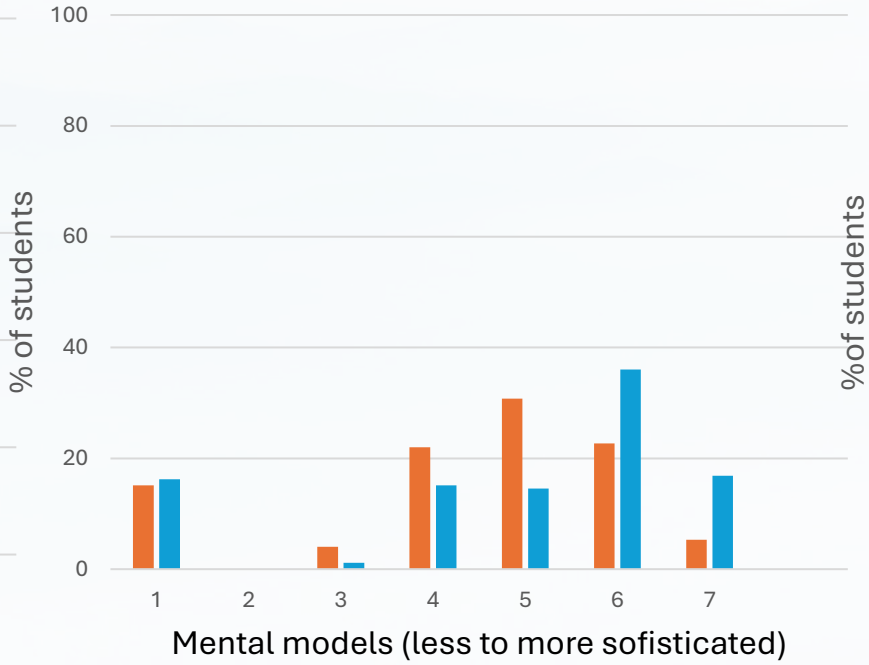
While in the 7th grade, the change is less significant compared to the previous ones.

Earth' layers 4th grade



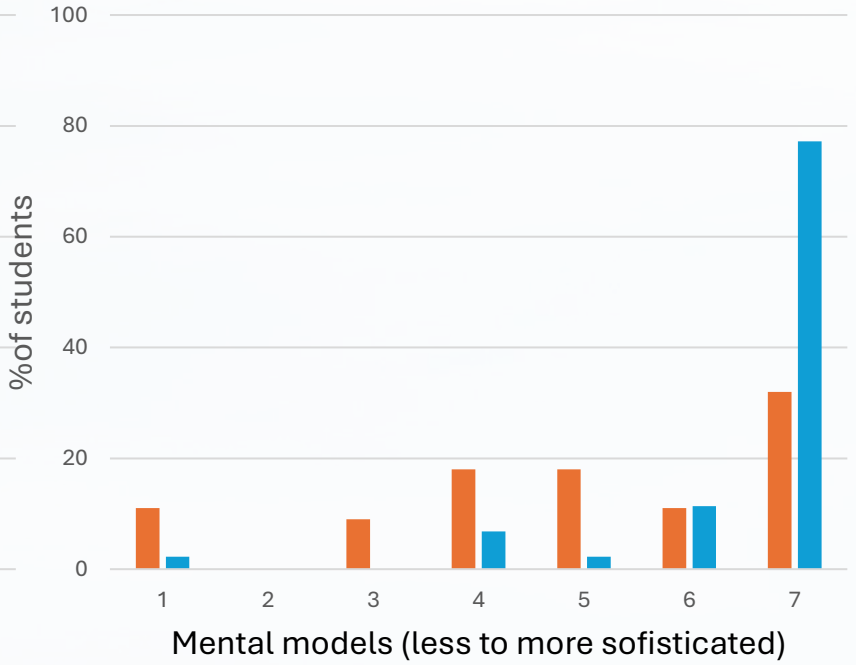
p< 0.001

Earth' layers 7th grade



p<0.01

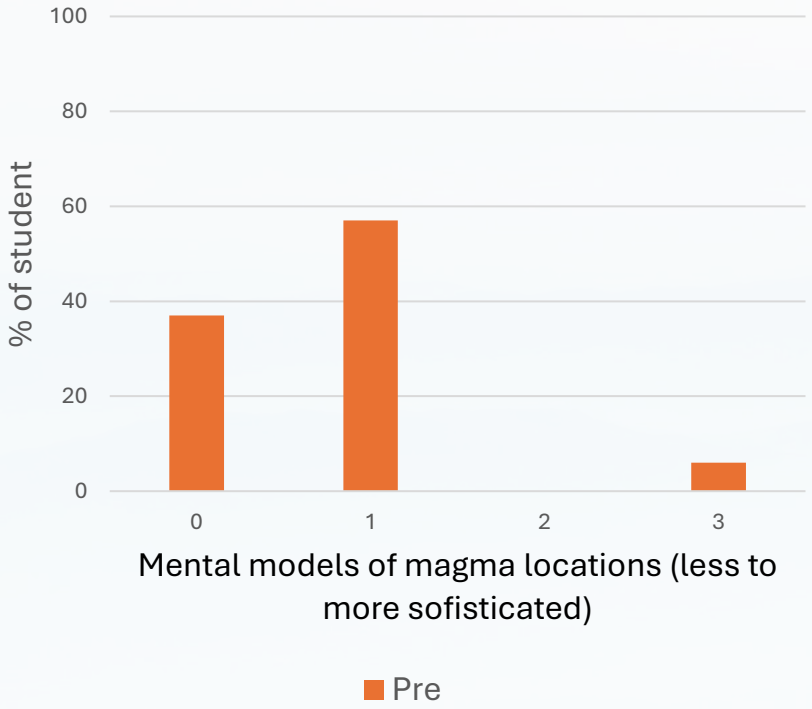
Earth' layers 11th grade



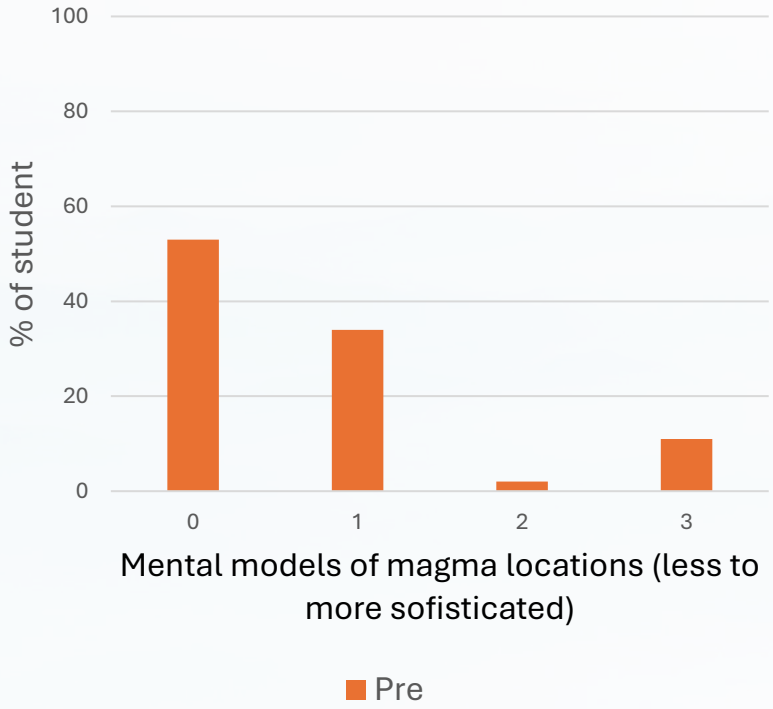
p< 0.001

Results: Magma location PRE

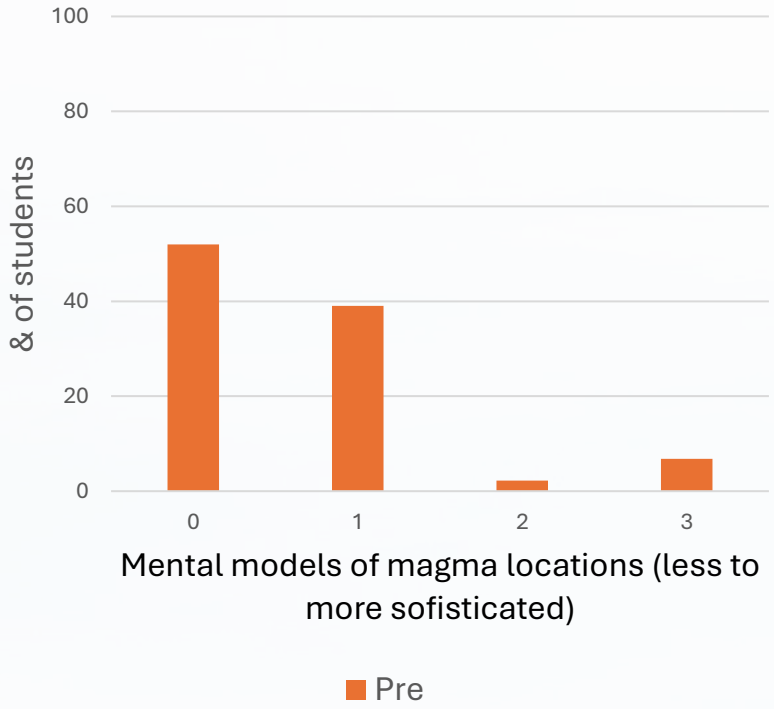
Magma location 4th grade



Magma location 7th grade



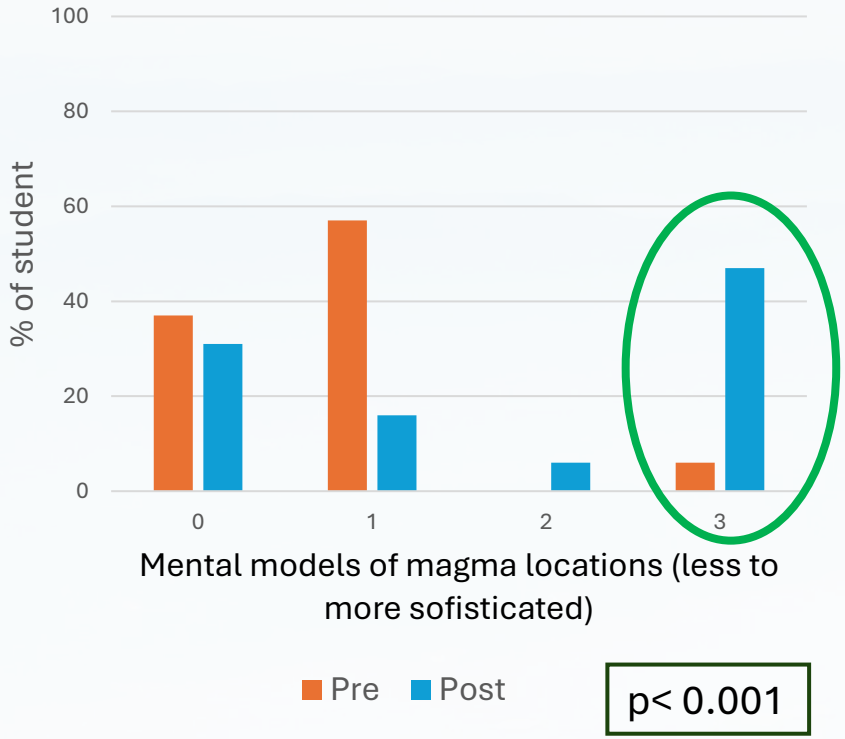
Magma location 11th grade



Results: Magma locations PRE-POST

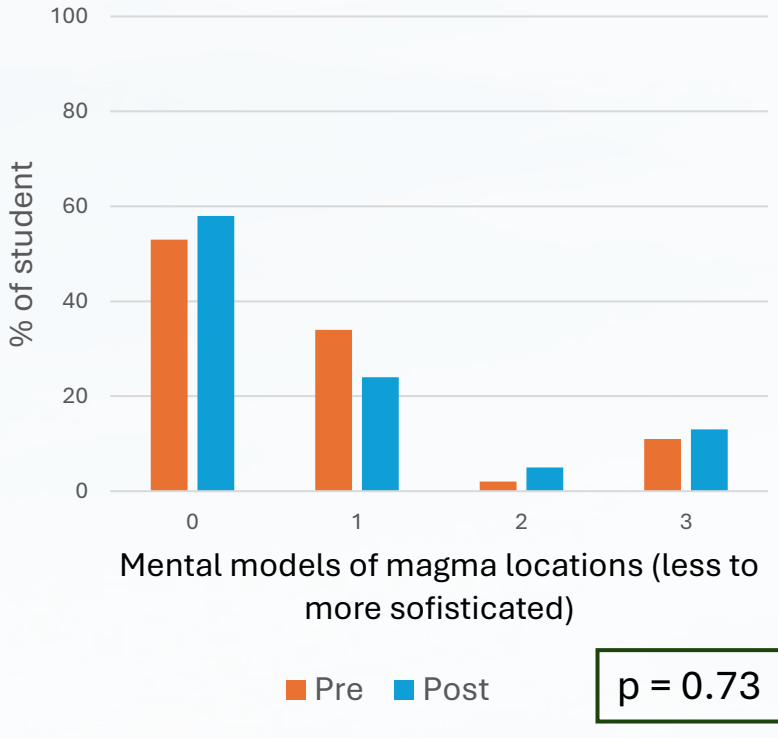
Regarding the location of the magma, there are no statistically significant differences between 7 th and 11 th grade, since many students do not place it in the scientifically correct place; most place it in the Earth's core or center.
However, after the implementation, 4th grade students identified magma in the more sofisticated or scientifically correct location, which is the mantle.

Magma location 4th grade



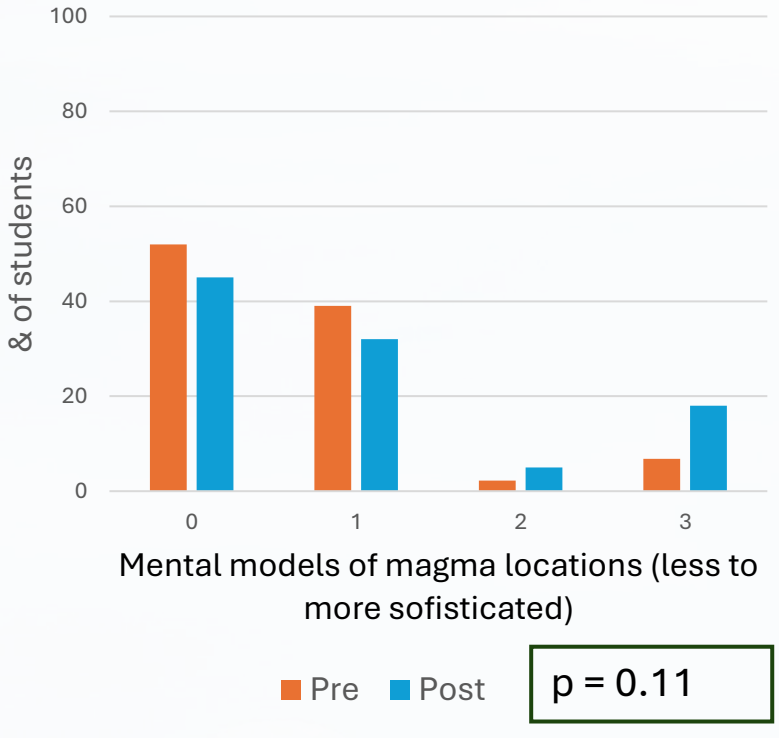
p< 0.001

Magma location 7th grade



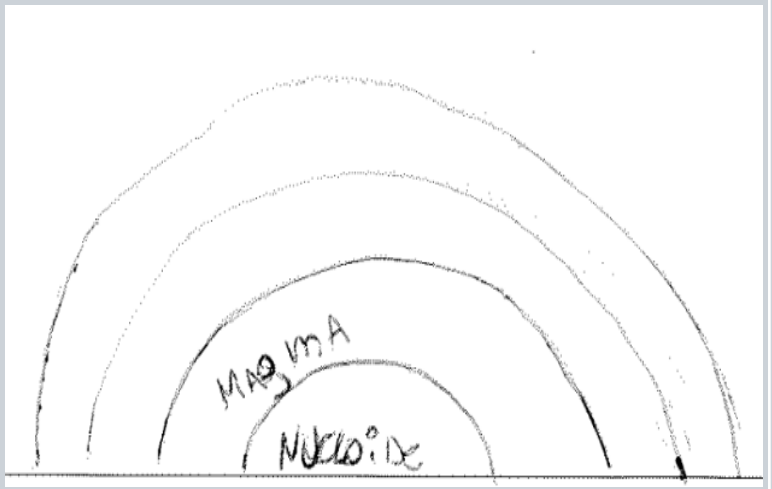
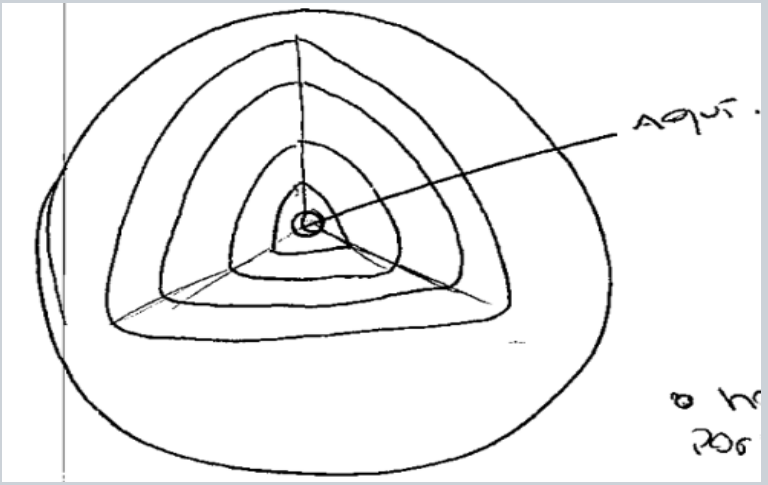
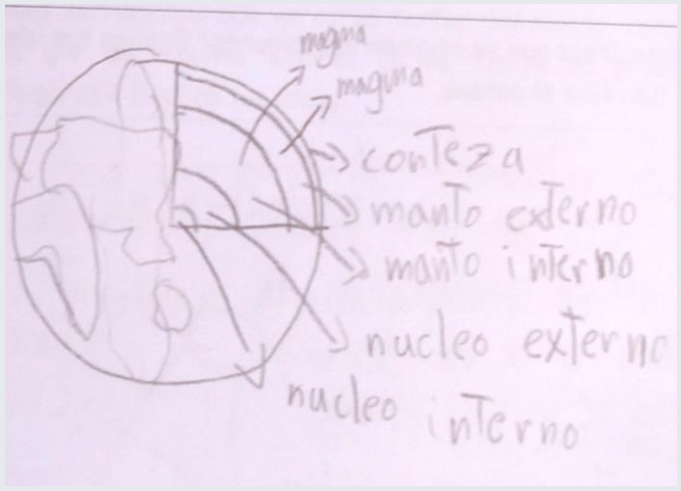
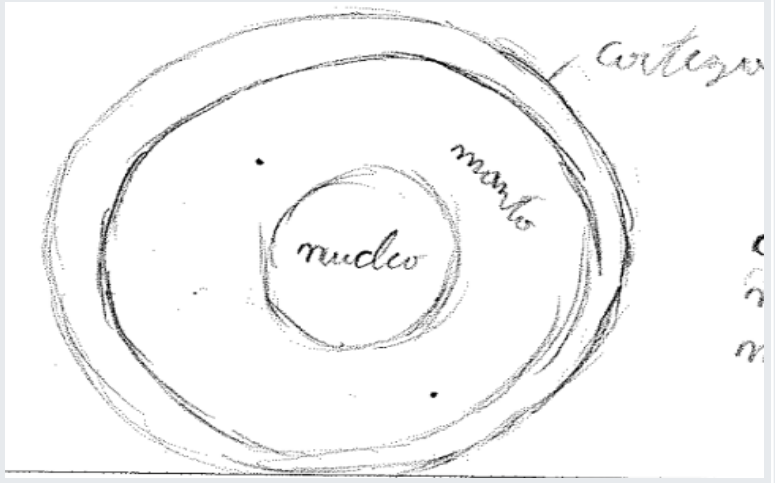
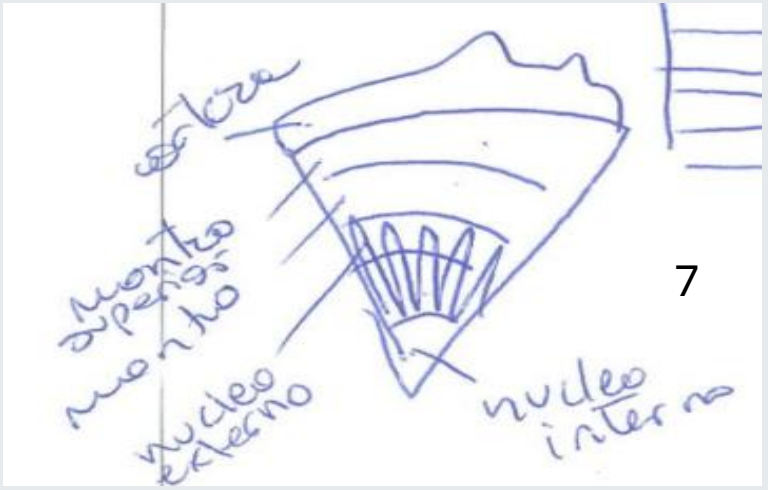
p = 0.73

Magma location 11th grade



p = 0.11

Example students' drawing: Layers and magma locations PRE-POST

	4 th	7 th	11 th
PRE			
POST			

Discussion and conclusions

- Students' mental models change differently depending on their educational level and concepts about the Earth's internal layers and the location of magma.
- The concepts about Earth's internal layers proved to be more consistent and effective across all grades, while the location of magma only showed significant improvements in 4th grade.
- In concepts about the location of magma, in 7th and 11th grade, changes were not statistically significant, suggesting that preconceptions internalized are difficult to change.

Limitations and projection

Expand the research by increasing the sample of 4th and 11th grade students, to be representative of the Chilean context.

Analyze the PCK in earth of teachers who implement the intervention to relate it to students' knowledge.

Conduct longitudinal research with 4th-grade students to monitor their Earth Science knowledge and analyze possible changes

Mental Models of the Earth's Internal Dynamics in Chilean Students: The Effect of Implementation with Strategies for Teaching Earth Sciences

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THANKS VERY MUCH FOR YOUR ATTENTION !

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