

Geologic models for exploration of dynamic Earth (GEODE)

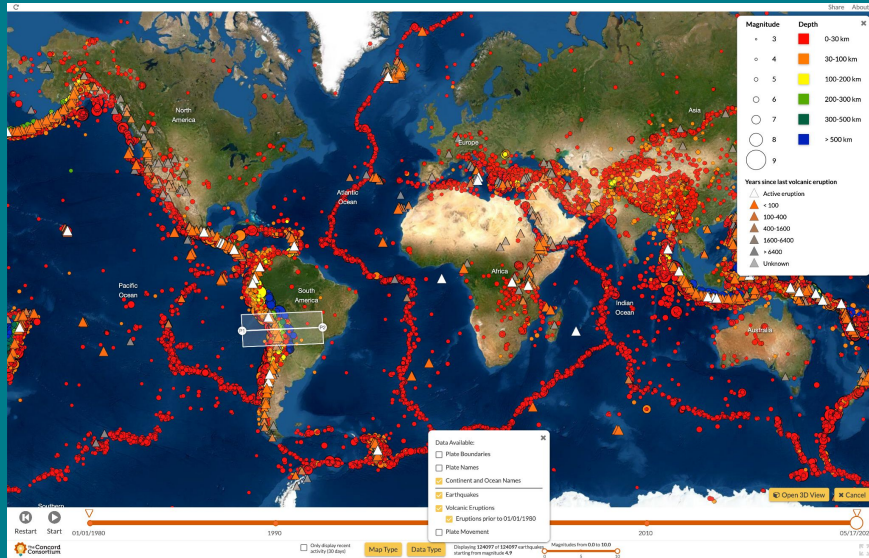
Context of the Work

The goal of GEODE is to design transformational geodynamic modeling software and curriculum materials that help middle and high school Earth science students develop a causal, mechanistic, and model-based scientific understanding of plate tectonics.

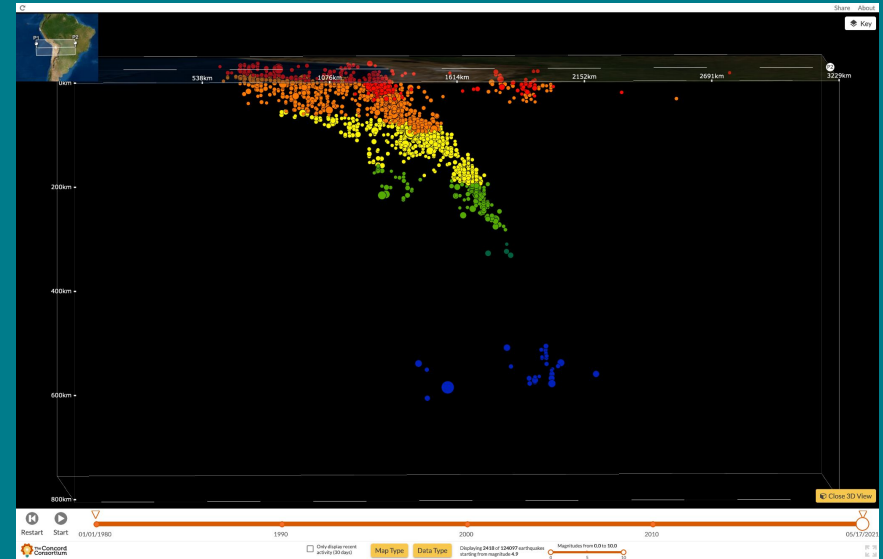


Products

[Seismic Explorer](#), a data visualization tool, enables students to explore earthquake and volcanic eruption data.



Earthquake and volcanic eruption data are displayed along a timeline

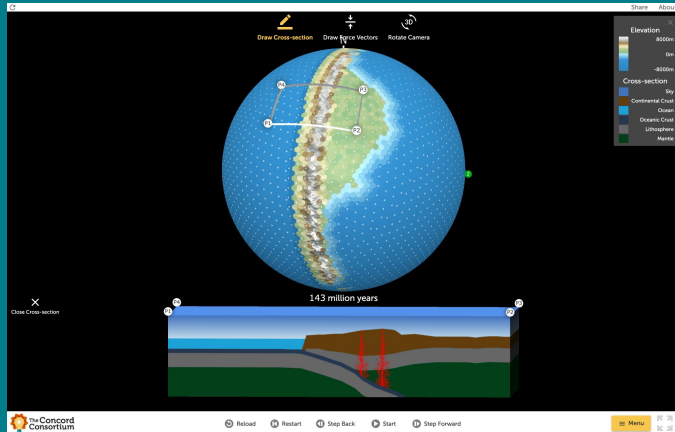
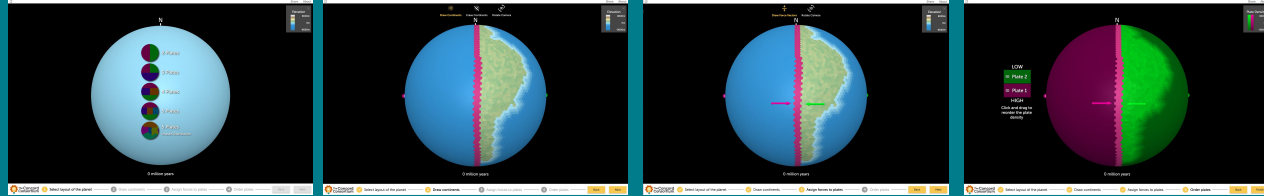


Students can draw three-dimensional cross-sections to earthquakes below the surface.

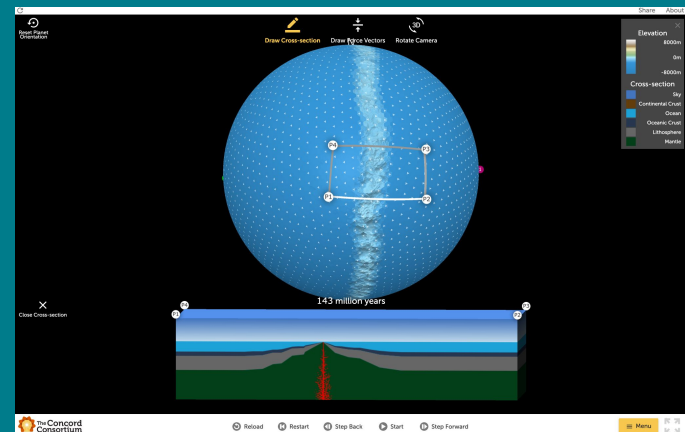
Products

[Tectonic Explorer](#), an Earth-like model, enables students to explore dynamic plate motions as part of a system.

Set up plate layout, continents, plate motion, and plate density with the Planet Wizard.



See dynamic plate motion create trenches and mountains in a cross-section view.



Rotate the planet to see the motion and landforms on the other side of a plate.

Products

[The Plate Tectonics module](#) helps students build a systems view of plate tectonics through focused case studies and interactions with Seismic Explorer and Tectonic Explorer.

An interactive [Teacher Edition](#) provides background information, teaching tips, and exemplar answers within the context of the module.

What will Earth look like in 500 million years?

Hi, Anonymous
In this module, you will consider the question: what will Earth look like in 500 million years? You will use data from Earth and models of a fictional planet to explore plate tectonics.

Estimated Time to Complete This Module: 345 minutes

1 Earth's moving surface



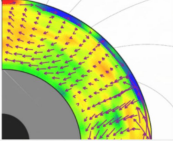
2 Interpreting Earth's clues



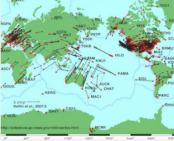
3 What happens with a lot of moving plates?



4 What drives plate motion?



5 What will Earth look like in the future?



This GEODE activity was developed under a grant from the National Science Foundation (DRL-1621176) in partnership with Pennsylvania State University.
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Teacher Tip

On the next few pages, your students will engage with real data from sources like NASA and the US Geological Survey. These data can be messy, and that's okay!

From this point until the end of the module, the goal is to support students' ongoing changes in thinking. *This is a great place to stop the class and elicit students' ideas.* What are their initial ideas?

Learn more about supporting students' changes in ongoing thinking.

Theory & Background

Teacher Tip

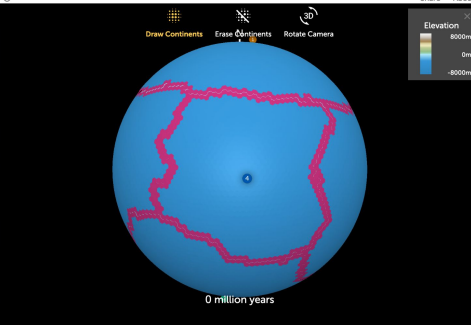


Google

Correct Question #3: Are all of the GPS stations on Earth moving in the same direction?
☐ yes
☐ no

Exemplar Question #4: What is your evidence?
Type answer here

Use Tectonic Explorer to try to form a supercontinent from at least three separate continents.



0 million years

Correct Question #20: Claim: Do you think that there will be a new supercontinent in 250 million years?
☐ yes
☐ no

Teacher Tip Question #21: Evidence: Collect evidence from Tectonic Explorer to support your prediction.
[Take a snapshot](#)

Exemplar Question #22: Reasoning: Explain how your evidence from Tectonic Explorer helps you defend your claim.
Type answer here

Exemplar Question #23: Prediction Limitations: Explain the limitations of Tectonic Explorer for making a prediction about the possibility of a supercontinent in the future.

Developing Causal Mechanistic Reasoning

We studied students' development of causal mechanistic explanations related to the plate tectonic system.

Explanations involve:

- **Entities.** The objects that comprise the system(plates and mantle).
- **Properties.** Well defined characteristics of each entity such as density and composition.
- **Activities.** Series of actions and interactions that result in changes over time that describe how the thermodynamic and gravitational forces produce observable geological outcomes (seismic activities, volcanic eruptions, plate boundaries, and landforms).

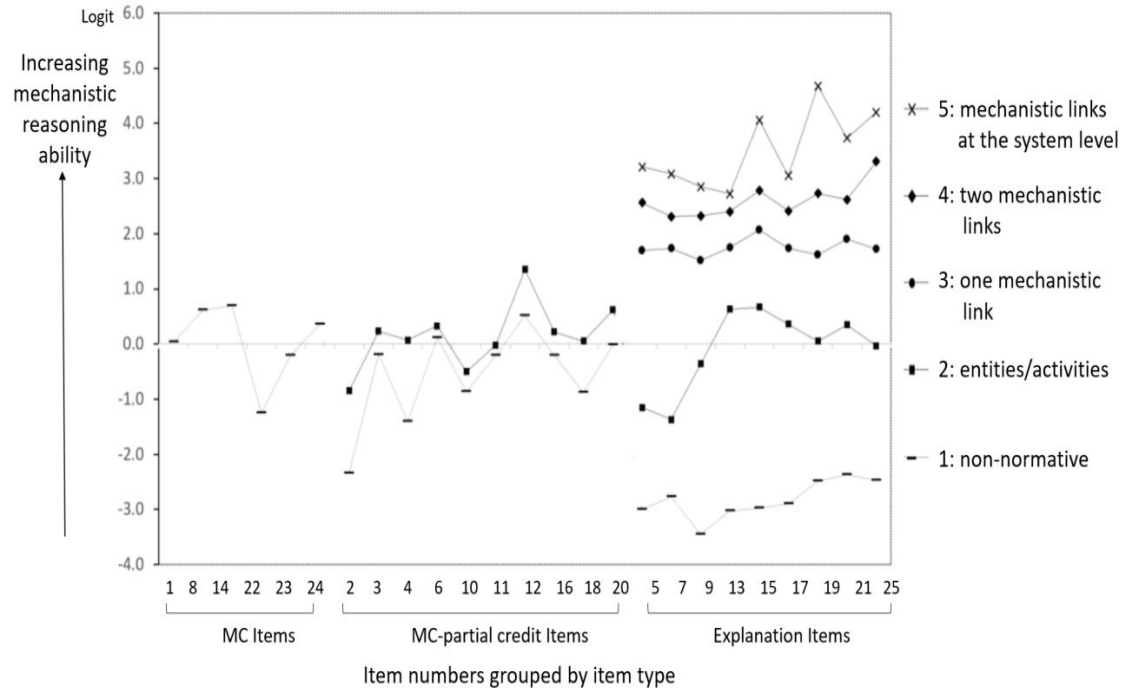
Example student explanation

"What moves the plates are movements in the mantle caused by heat currents because when the material near the bottom of the mantle gets heated by the core it becomes less dense and rises then the currents are separating near the crust pulling the crust apart by the heated material getting cooler, then becoming more dense causing gravity to pull down hard on it."

Results

Results of Rasch PCM analysis on the 25-item plate tectonics instrument indicated:

- A unidimensional construct related to causal mechanistic reasoning can be formed.
- Five levels of causal mechanistic reasoning grounds the formation of the construct
- Explanations can be used to measure students' application of mechanistic links.
- Multiple-choice questions require students ability to identify entities or activities, not causal mechanistic links.



Remote Online Teacher Professional Development

We designed online teacher educative materials to accompany the Plate Tectonics Module called the Teacher Edition (TED). TED is accessed entirely online and was developed to help teachers implement the materials. We researched:

- How teachers used TED to teach with the module
- To what extent their use of the materials correlated with student learning outcomes
- Which educative features of TED were most valuable and why

Teacher Tip

Exemplar

Question #20

Try to set up Tectonic Explorer to match the Aleutian Islands in a way that creates a chain of islands.

Take a snapshot of your best example of a chain of islands. Make sure to show a cross-section.

Take a snapshot

For students who are struggling to set up the Aleutians, refer them back to the instructions for the Andes, but ask them how the Andes and Aleutians are different.

Mountains like the Andes are created when a plate with oceanic crust meets a plate with continental crust.

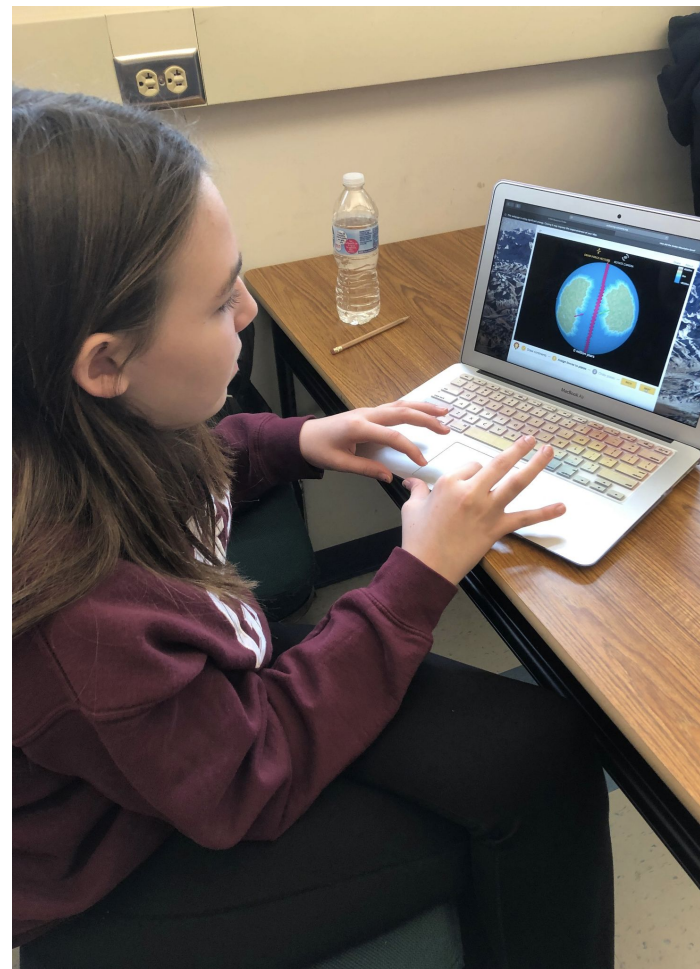
Island chains and arcs like the Aleutians are created when two plates with oceanic crust meet.

Results

This investigation of 26 middle and high school Earth science teachers was done entirely remotely using digital traces generated by teachers' use of TED, self-reports collected via post-surveys, and follow-up telephone interviews. We compared teacher logs to student logs and analyzed students' scores on associated pre- and post-assessments.

Results indicate that:

1. **Large variations existed** in the amounts and types of features teachers accessed.
2. **Middle school teachers accessed significantly more TED features** ($M=744$) than high school teachers including simulation support features ($M = 228$), $t(24) = 3.15$, $p < 0.01$.
3. **Teachers who used TED while in class with students posted significantly higher student learning gains** (Mean Effect Size = 1.35 SD) as compared to those who did not (Mean Effect Size = 0.82 SD), $t(24) = 2.42$, $p < 0.05$.
4. **Teachers assigned the most value to TED features that focuses on student assessment support.**



Research on Teacher Talk Moves

We characterized teachers' support of authentic disciplinary norms in the classroom as *purposeful* talk and analyzed classroom videos based on the Ambitious Science Teaching framework (Windschitl, Thompson, & Braaten, 2018).

We investigated the relationship *between the talk moves used by a teacher and the norms established through classroom talk* to see whether the norms emerge through progressive discourse (Bereiter, 1994).

Results

- Teachers' goals may not align with one another, but these goals play a role in how each teacher responds to student discourse.
- When mentor teachers provide feedback to preservice teachers, the purpose of the actions mentioned by this feedback is not explicit; the implementation of the suggestions therefore may not align with the implicit goals of the mentor teachers.

Project Impacts

- Contributed to the fields understanding of student learning about complex dynamic geoscience concepts, specifically around plate tectonics.
- Tectonic and Seismic Explore generated enthusiastic interest from educators and researchers.
- Submitted/Published: 4 research papers, 5 teacher papers, and 7 newsletter articles.
- Presented to communities of interest including: National Research Council, Harvard Smithsonian Astrophysics Observatory, IRIS, GSA, NSTA, ESIP, NESTA, NARST, and AERA.
- Wide dissemination of materials and increase in number of users:
 - 2019-2020: Students 13,353, classes 603, teachers 274
 - 2020-2021: Students 21,911, classes 1086, teachers 585

To learn more, visit

concord.org/geode

learn.concord.org/geo-platetectonics

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