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.

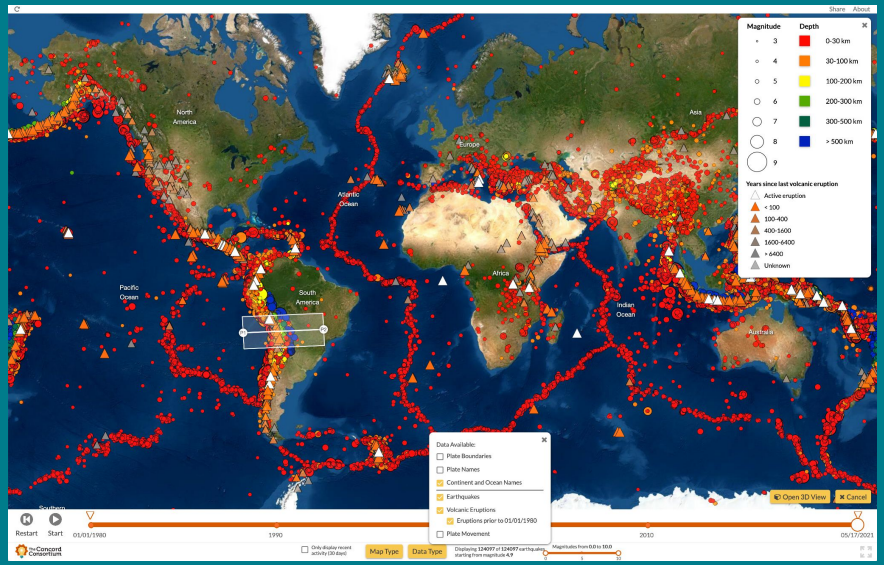
The Concord Consortium

NSF

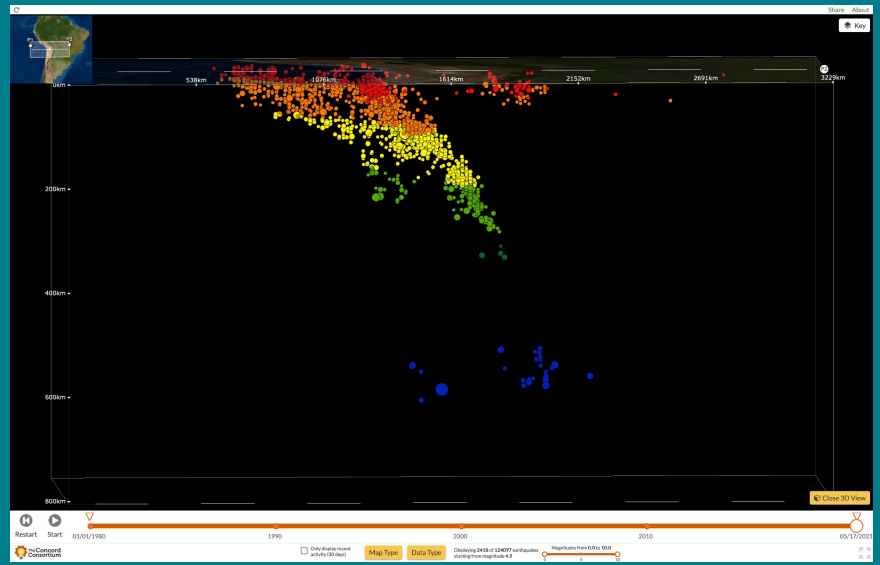
PennState

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.

The Concord Consortium

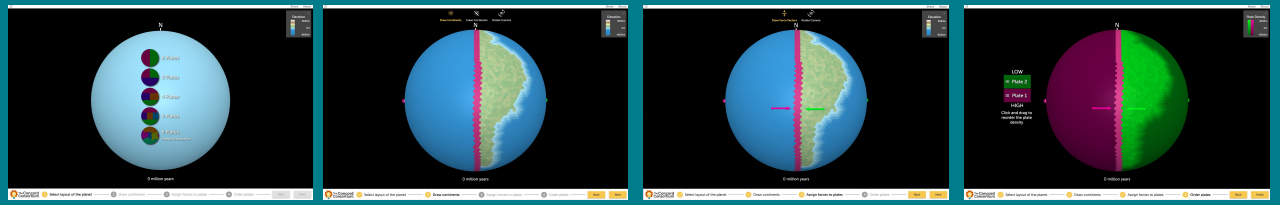
NSF

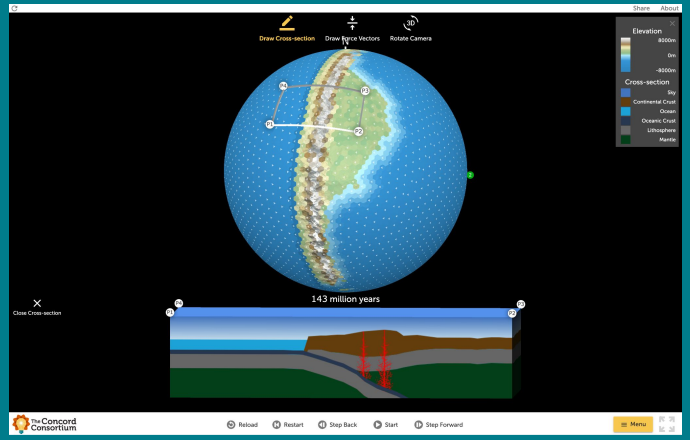
PennState

Products

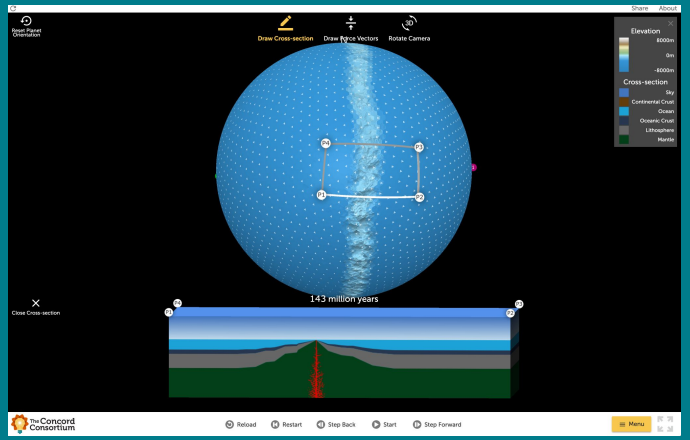
Tectonic Explorer, an Earth-like model, enables students to explore dynamic plate motions as part of a system.

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.

The Concord Consortium

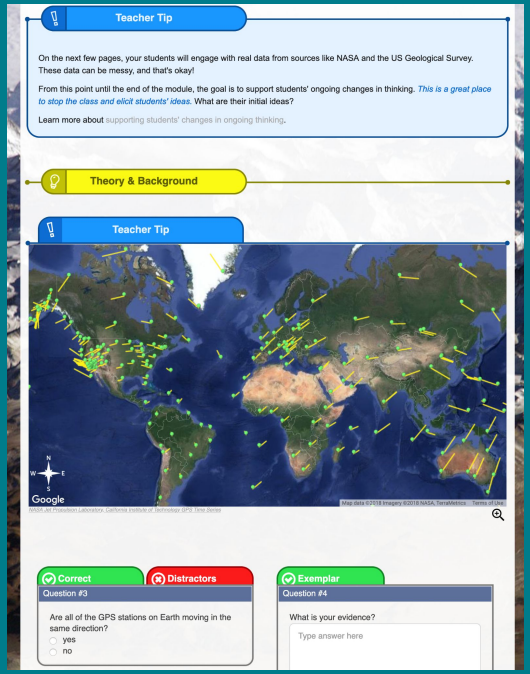
NSF

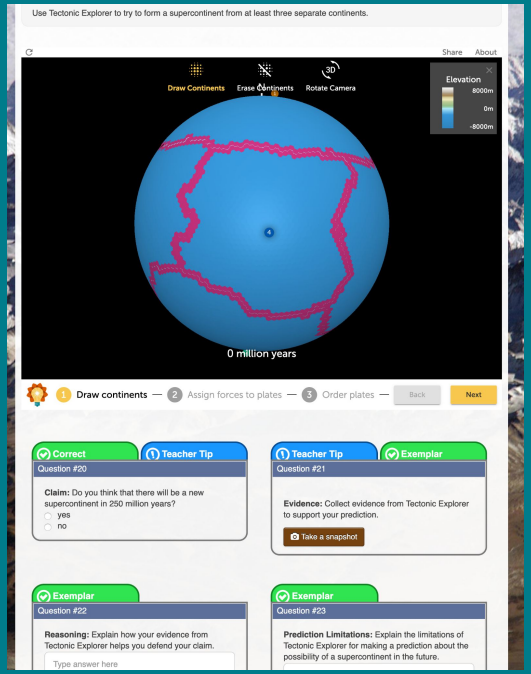
PennState

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.





The Concord Consortium

NSF

PennState

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).

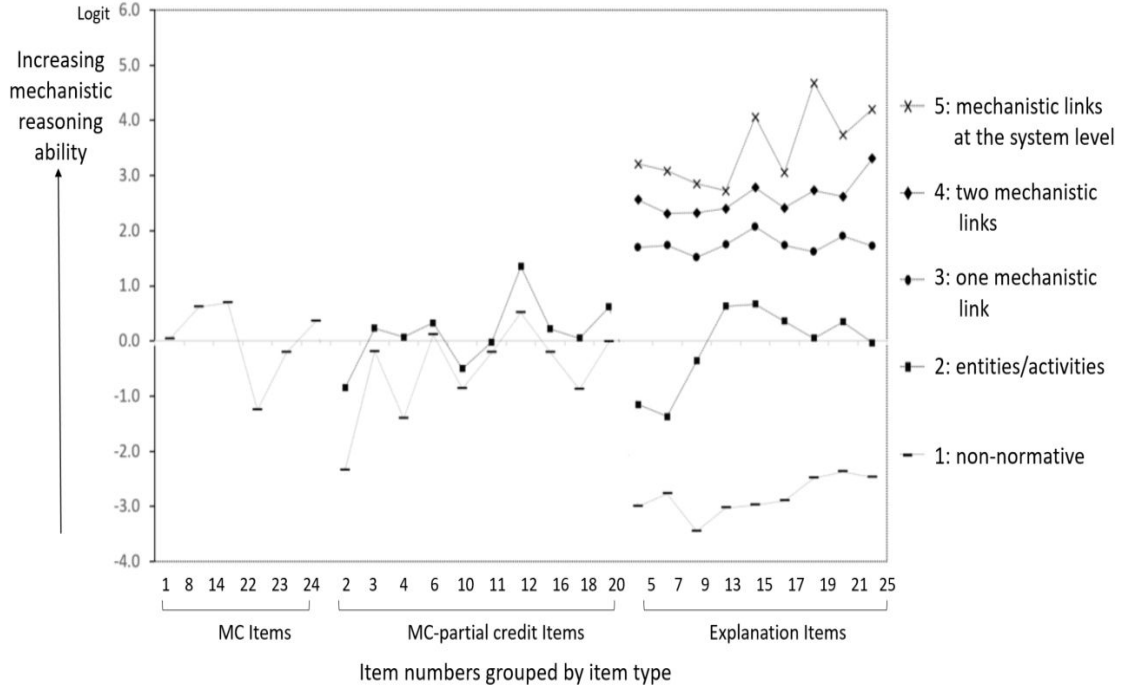
Example student explanation

"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:

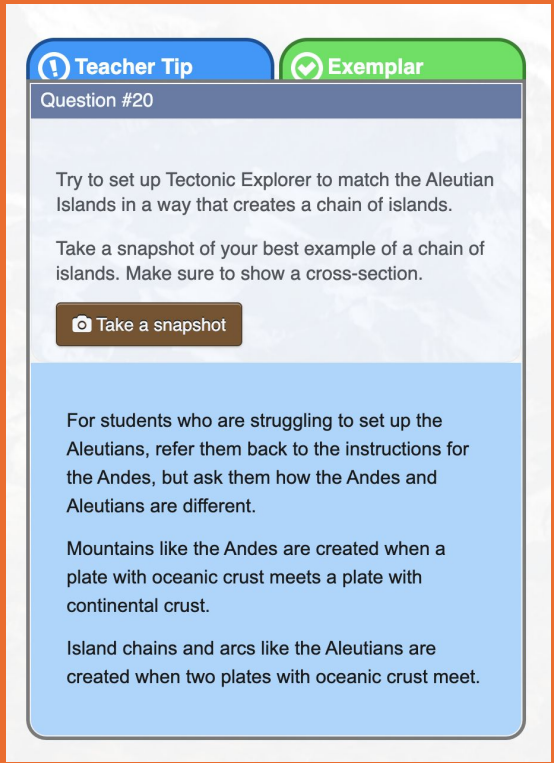
- A unidimensional construct related to causal mechanistic reasoning can be formed.
- Five levels of causal mechanistic reasoning grounds the formation of the construct
- Explanations can be used to measure students' application of mechanistic links.
- Multiple-choice questions require students ability 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**

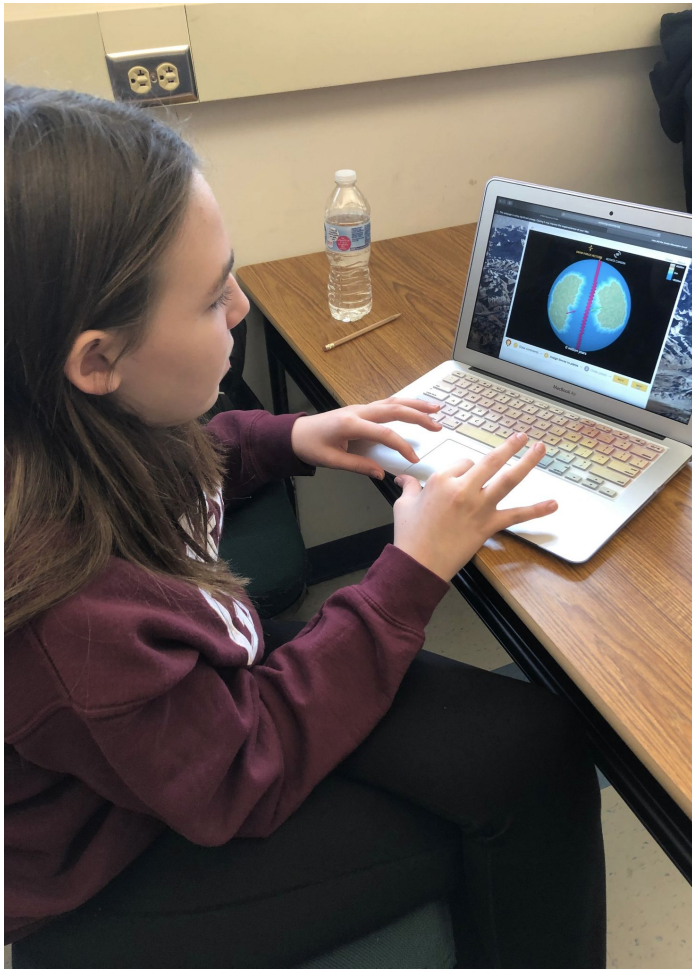


Results

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**.



The Concord Consortium

NSF

PennState

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

This material is based upon work supported by the National Science Foundation under Grant No. DRL-1621176. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.