Using 3D Modeling to Promote Design Thinking and Inquiry in an Introductory Geology Lab

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Megan Plenge, Geological Sciences, UNC-CH

BEAM
BE A MAKER

Objectives

1. To engage students in the first steps of the scientific process in an intro lab.
   a. Develop scientific questions and formulate hypotheses
   b. Design and construct models to test hypotheses

2. To understand how geoscientists use models as tools to study Earth
   a. Simplifying complex systems
   b. Use model results to predict past/ future events or conditions

Context

- 250-350 students per semester (15-20 sections, 12-20 students per section)
- 13 2-hour lab sessions per semester
- 8 hours in-class time for the project
- Makerspace with free materials on campus: www.beam.unc.edu

Model: Permeability and oil flow in aquifers

Steps in the project

1. Exposure to physical and conceptual models in labs
2. Complete orientation for UNC's Makerspace, watch video lecture on scientific models , get project resources and ideas
3. Groups of 2-4 develop project proposals, including research questions, hypotheses, and model/ experimental designs
4. Proposals are reviewed by peers and TA
5. Groups submit a draft model or detailed plan
6. Groups present final models + results

Example with Feedback

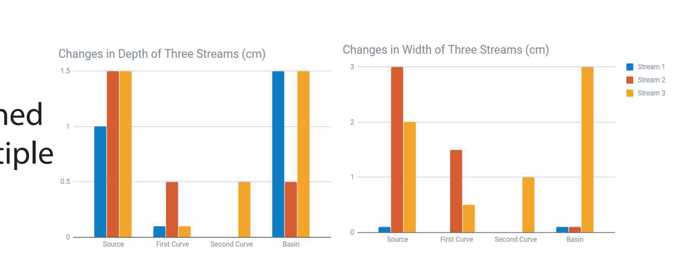
Question: How does stream curvature affect erosion?

Hypothesis: More curvature results in more erosion

Model: Cardboard box with soil & streambed 1.5cm wide x 2cm deep

Experiment: 1 cup of water was poured, average width, depth measured and displaced sediment observed

Feedback from TA: Students need to do experiment earlier in semester as they learned too late what their experiment lacked: multiple trials and real-world data to compare with modeled data.



"The most common misunderstanding about science is that scientists seek and find truth. They don't -- they make and test models."
Neil Gershenfield (2011)

Example Models and Experiments

Question: How many degrees does Earth's temperature have to rise for the city of Honolulu to be submerged due to sea level rise?

Model: 3D-printed topographic map of Oahu, mathematical model predicting sea level rise with given temperature increase

Experiment: Measured height of water added relative to datum to drown Honolulu, scaled to Earth system and calculated temperature

Question: How does temperature of magma impact flow?

Model: 3D printed volcano, tahini

Experiment: qualitative & quantitative changes in flow at different temperatures

Question: How does ground material impact earthquake shaking and building collapse?

Model: Aluminum pan filled with different materials with spaghetti building on an orbital sander.

Experiment: Place pan on orbital sander for 20 seconds and measure movement of building post-shaking

Video footage: https://drive.google.com/file/d/10_fiEju3j-55FbeZ-EVjJkxXkjR2SHqm/view?usp=sharing

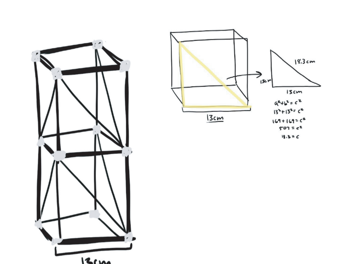
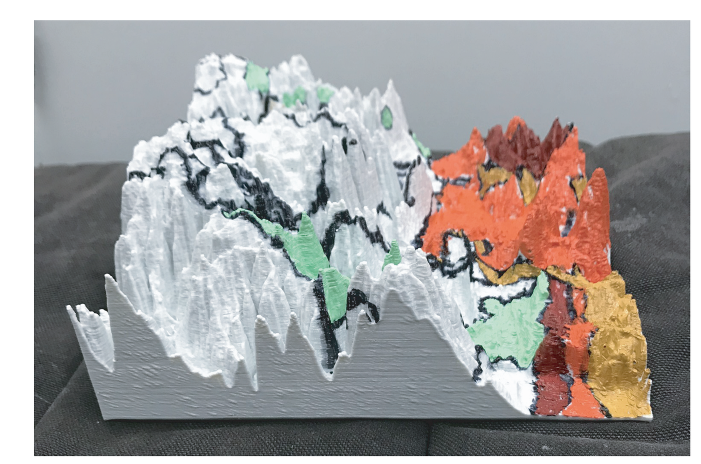


Table 1	Sand (Clay)	Mud (Silt)	Playdough (Bedrock)	Jello ("Regular" soil)
Distance moved (in cm)	1 cm	0 cm	2 cm	0 cm
Visual description of what happened	The sand buried the structure.	The structure completely collapsed.	The vibrations moved the house on the surface	The structure frequently moved up and down, but not horizontally.



Question: Where do we expect to see flooding in Chapel Hill?

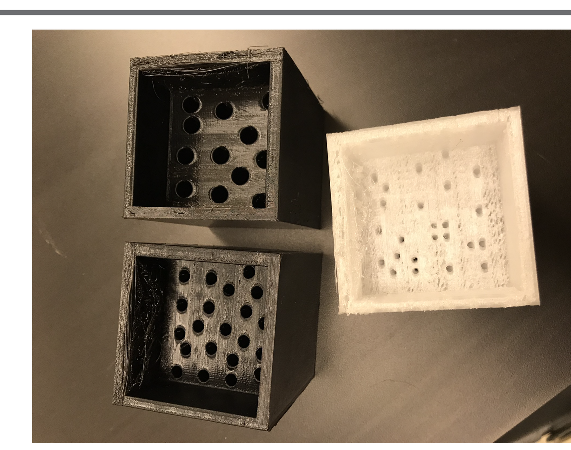
Model: 3D print-out of Chapel Hill with 50x vertical exaggeration and geologic units painted on

Experiment: Water was poured over model and observations were made on where water collected.

Question: How does size and density of impactors affect ejecta patterns?

Model: Cocoa powder and flour, impactors include orange, ping pong ball, etc.

Experiment: qualitative; observation of ejecta patterns



Question: How does rate of travel of oil through rocks relate to rock porosity/permeability?

Model: 3D printed "rocks" including holes/different print densities

Experiment: qualitative & quantitative changes in flow at different temperatures

Question: Which cities are in the most danger due to Mt. Fuji erupting?

Model: Modeling clay and corn syrup (after the group failed to make their 3D model based on topography using touchterrain.geol.iastate.edu) (Hasiuk et al., 2017)

Experiment: Multiple trials of pouring corn syrup down model volcano

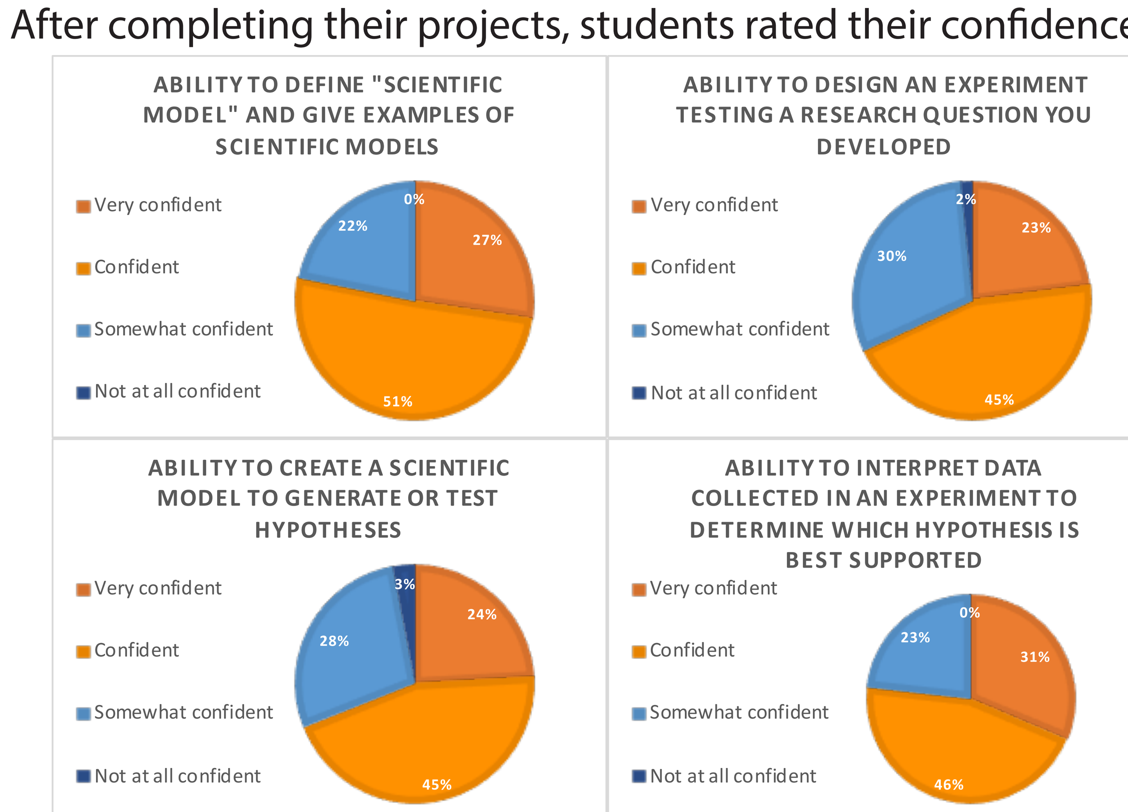
Students learned: How to adapt when their initial model failed

5-point rubric: Model + Experiment

Aspect of project being graded	1 point	2 points	3 points	4 points	5 points
Experiment: Raw Data (15 points total)					
Presentation of raw data & data collection method	Data or collection method missing	Data and collection method both included, but missing key details	Data and collection method both included, but missing minor details	Data and collection method both included, and well explained	Data and collection method both included, well explained, and perfectly detailed
Ability of data to test hypothesis	Collected data and method of collection do not clearly relate to hypothesis	Collected data or method of collection does not clearly relate to hypothesis	Collected data relates to hypothesis, but this data alone will not support/repudiate hypothesis	Collected data clearly relates to hypothesis, and is sufficient to support/repudiate hypothesis	Collected data clearly relates to hypothesis and ALL relevant data necessary for hypothesis testing is included
Sufficient data collected to answer question	No quantitative data included, very few data points collected	No quantitative data included, sufficient data points for testing hypothesis included	Little or no quantitative data included, sufficient data points for testing hypothesis included	Quantitative data and a sufficient number of data points, multiple trials not conducted	Quantitative data and a sufficient number of data points, multiple trials conducted
Experiment: Interpreted Data (20 points total)					
Presentation of interpreted data	Data are presented in graphic or tabular format, but is a reiteration of raw data and is not detailed enough to be interpreted by grader	Data are presented in a graphical or tabular format, but is is a reiteration of raw data and lacks in detail/clarity	Data are presented in graphical or tabular format, but lack in detail and clarity, and do not include calculations, trend lines, etc.	Data are presented in a clear, well-labeled graphical or tabular format, with few to no calculations / other analyses	Data are presented in a clear, well-labeled graphical or tabular format with trend lines, calculations or other analyses included
Clear argument for supporting/ repudiating hypothesis	Author makes an argument for data supporting/ repudiating hypothesis, but it is flawed/unclear	Author makes an argument for data supporting/ repudiating hypothesis, but it is not detailed or informed enough	Author makes an argument for data supporting/ repudiating hypothesis that is clear but requires slightly more detail to be persuasive	Author makes an argument for data supporting/ repudiating hypothesis that is clear and detailed	Author makes an argument for data supporting/ repudiating hypothesis that is clear, detailed, and persuasive without relying on additional data
Modeled data interpreted within real-world context	Author mentions a potential real world context, but does not relate it to modeled data	Author mentions a potential real world context and vaguely describes how modeled data relates	Author discusses real world context in which modeled data can be useful, but does not include specific examples	Author discusses real world context in which modeled data is useful, including specific examples	Author discusses real world context in which modeled data is useful, and includes actual data from specific examples for comparison
Analysis of interpreted data	Usefulness of data set in answering research question is included as a "yes/no" statement regarding how useful data are	Usefulness of data set in answering research question analyzed in broad terms, but with no specific details	Usefulness of data set in answering research question analyzed in terms of 1 of the following: potential errors, simplifying assumptions, or the role of other Earth systems	Usefulness of data set in answering research question analyzed in terms of 2 of the following: potential errors, simplifying assumptions, and/or the role of other Earth systems	Usefulness of data set in answering research question analyzed in terms of potential errors, simplifying assumptions, and the role of other Earth systems
Model (20 points total)					
Usefulness of model in answering research question	You made a model: but why?	Model is a demonstration rather than a tool, and a poor demonstration for answering your research question	Model is a demonstration rather than a tool, but an excellent demonstration for answering your research question	Model is a tool for answering your question, but a different tool may have been more effective	Model is an excellent tool for answering you research question/ testing your hypothesis
Design of Model	The design of the model is unable to test your hypothesis	The model design is missing at least one major element and cannot sufficiently test your hypothesis	The model design is missing at least one minor element for being able to test your hypothesis	The model design is capable of testing your hypothesis	The model design is a great one for testing your hypothesis
Functionality of Model	The model was designed but never created, so functionality cannot be tested, though the design/ plans look as though they would work	The model does not function as designed and cannot be made to work, and no back-up was created	The model does not function as designed, but can collect flawed data, OR a back-up of the model was implemented but not able to collect data sucessfully	The model functions, but not as intended, and data collection is flawed, OR a back-up plan for the model was implemented and able to collect (flawed) data	The model functions as designed, OR a back-up plan for the model was sucessfully implemented
Back-up plan for Model/Data Collection	A vague back-up plan for the model/data collection was outlined	A back-up plan was outlined, but not one that could be implemented (e.g., just as complicated as original plan)	A detailed back-up plan for the model OR data collection was outlined	A detailed back-up plan for the model AND data collection was outlined, but would not sucessfully test hypothesis	A detailed back-up plan for the model AND data collection was outlined, including sources for data if needed, and would sucessfully test hypothesis

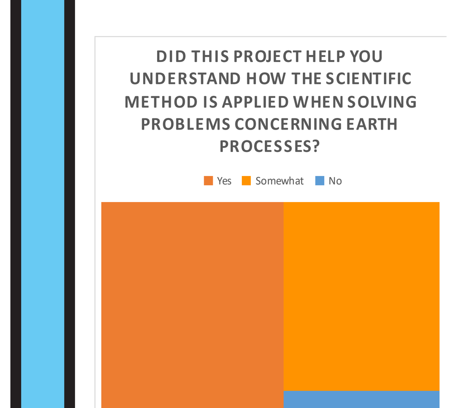
Student Survey Results

- After completing their projects, students rated their confidence:



Outcomes and Future Plans

- **>60% of students felt confident in experimental design**
- **Only ~50% of the class feel the project helped them understand how models are used to solve Earth Science problems**



- More in-class time will be devoted to project
- Groups will have individual meetings with TA at multiple points during semester
- Students will do a trial of experiment earlier in semester and report what they learned
- Students will have reflection activities linking project to real scientific studies

Acknowledgements / Citations

- Thanks to UNC's QEP team, the UNC Department of Geological Sciences, the BeAM lab, and my TAs for the 2017-18 academic year

Hasiuk et al. (2017). TouchTerrain: A simple web-tool for creating 3D-printable topographic models. Computers & Geosciences 109: 25-31.