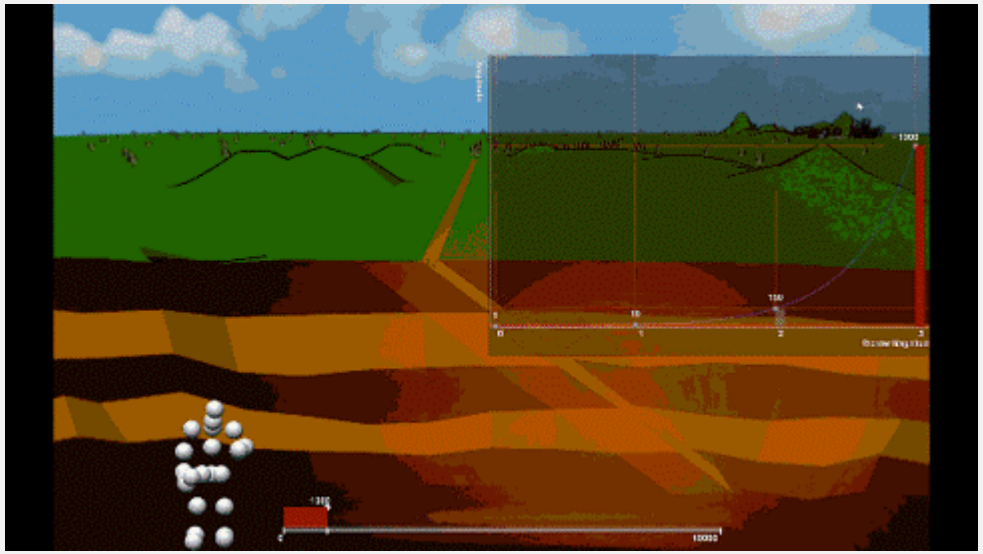
WHEN 2 EQUALS 10 TIMES 1

Facilitating reasoning about exponential growth with an embodied simulation



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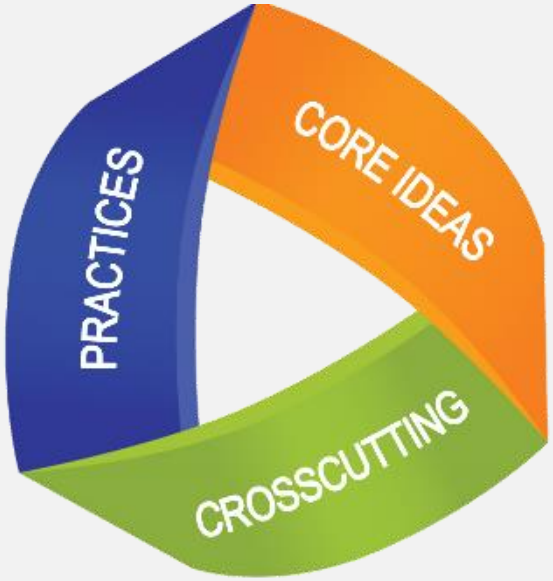
PROJECT INFORMATION

Embodied **L**earning **A**ugmented through **S**imulation **T**heatres for **I**nteracting with **C**ross-**C**utting **C**oncepts in **S**cience

http://elastics.education.illinois.edu/

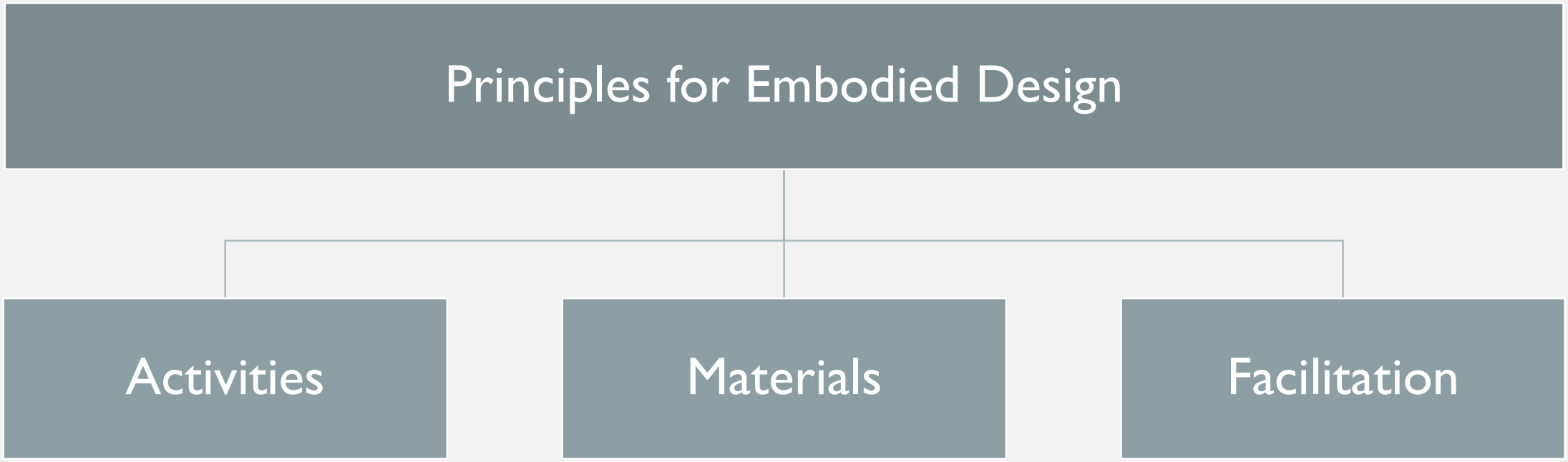
NGSS'S CROSSCUTTING CONCEPTS



Scale, Proportion, and Quantity

In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

(NGSS, Appendix G, pg 1)



(Abrahamson & Lindgren, 2014)

Principles for Embodied Design

Activities

Draws on learners preexisting capacity to orient and mobilize in real or virtual 3D space

Materials

Provides opportunities for learners to find meaning in orchestrated environments (tutors, virtual worlds, teachers etc.)

Facilitation

Supports learners to physically and conceptually engage with the environment

KEY QUESTIONS

Given an embodied simulation environment, where learners can sustain a tacit sense of meaning through corporeal activity while interacting with the simulation, how we can take learners through an optimal process of engaging with embodied simulations to accomplish learning? (Abrahamson & Lindgren, 2014)

Given an embodied simulation for exponential growth, what forms of facilitation moves supported student reasoning about exponential growth?

THEORETICAL BACKGROUND

STUDY DESIGN

METHODS

FINDINGS

CONCLUSIONS

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EMBODIED LEARNING

- Research in embodied cognition that shows there is a fundamental connection between the somatic actions and how people think and reason (Barsalou, 2008, Gallagher, 2005; Glenberg, 2010; Shapiro, 2010; Wilson, 2002)
- Giving learners specific physical experiences or prompting particular actions can generate learning (Goldin-Meadow et al., 2009; Kontra et al., 2015; Lindgren et al., 2016)
- Abstract ideas such as high-level mathematics have embodied foundations (e.g., Lakoff & Núñez, 2000)

UNDERSTANDING SCALE AND QUANTITY

Students struggle with…

- conceptualizing large (and small) numbers (Cheek, 2012)
- differentiating between linear and non-linear processes, often inappropriately applying linear reasoning to non-linear problems (Modestou, & Gagatsis, 2007; Wagenaar, 1982)
- interpreting and working with logarithmic or exponential scales
  - often believe that linear changes on the scale result in linear changes on the measure (Francek, 2013).

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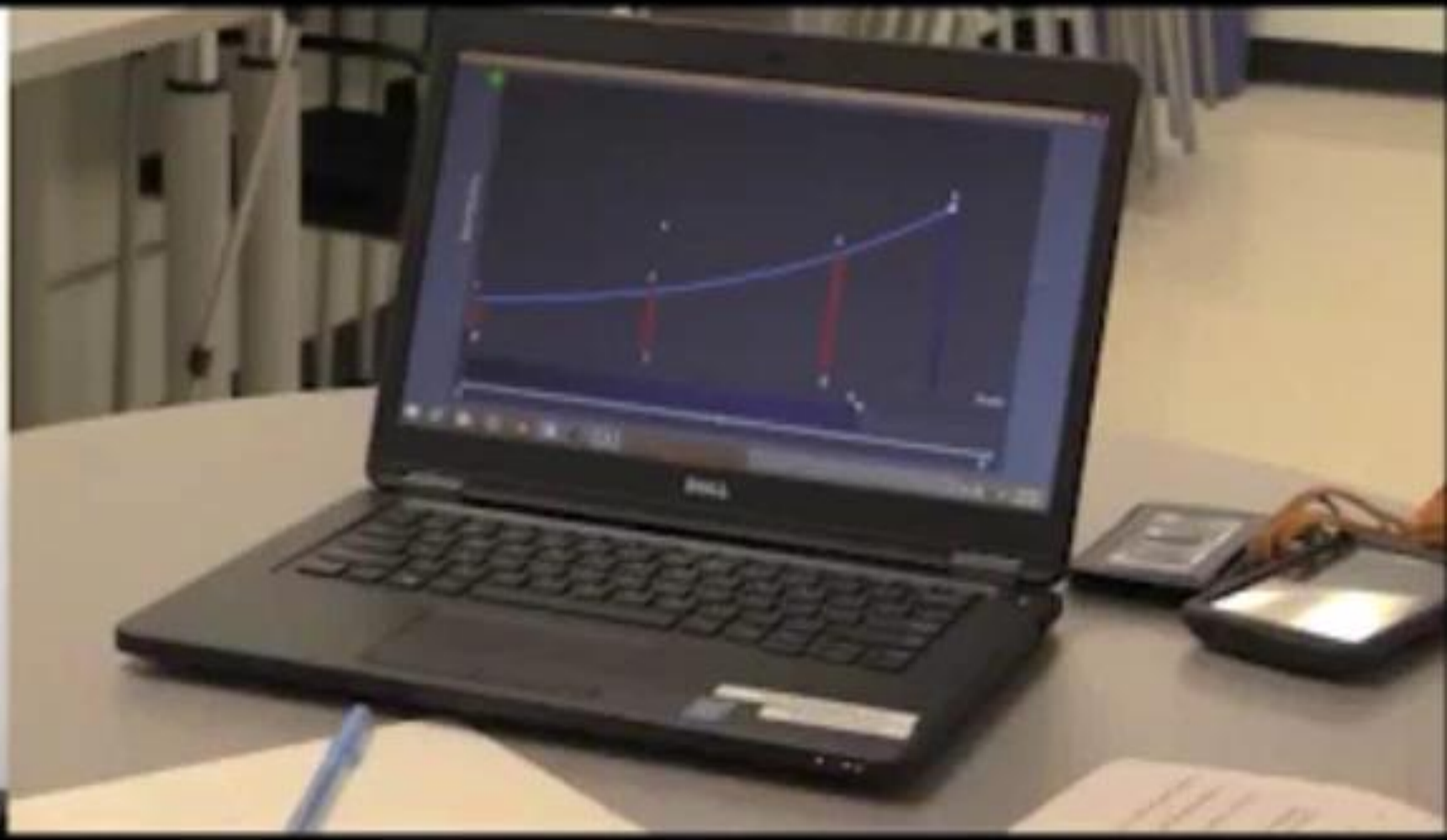
PILOT INTERVIEWS with middle school, high school, and undergraduates

Gestures related to the conceptual meaning of a mathematical operation are associated with more sophisticated reasoning and problem solving. (Alameh, Morphew, Mathayas, & Lindgren, 2016)



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- Pre and post test:
  - Game show problem:

    Would you prefer to receive a prize of $1 that doubles 30 times or $1000 that adds for 30 times?
  - Earthquake problem:

    How does the change in amplitude compare between earthquake from 2 to 5 and then 5 to 8?

- Task-based interview:

1. Training phase: 1. Introduce mathematical gestures (+, -, x, /)
   2. Practice using gestures to calculate numbers

2. Task phase: Calculate values using simulation in different contexts. i.e. calculate the number of rabbits that would be present if the population doubled every month for a year, and the number of bacteria cells present in a population that increased by a factor of ten every day.

- Participants: 22 high school students (13 males and 9 females) from surrounding area of a large Midwestern University
- Interviews took place during free periods or after school sessions and were video-recorded.
- Scoring and coding scheme
- Scoring agreement: 84% followed by 100% post discussion

Table 1: Number of students who correctly answered the calculation tasks (N = 22)

Calculation tasks	Pre	Improve	Regress
Would you prefer to receive a prize which $1 doubles for 30 times or a prize which adds $1000 for 30 times?	14 (70%)	3 (15%)	1 (5%)
Explanation for selecting your option.	2 (10%)	9 (45%)	0
How would you calculate the total amount in the doubling option?	5 (25%)	5 (25%)	0
Estimate how much money you would receive with the doubling option.	0	9 (45%)	0
What is the ratio of amplitudes between two earthquakes?	10 (50%)	6 (30%)	0
How does the size of two changes in amplitude (From 2 to 5 and from 5 to 8) compare to each other?	8 (40%)	5 (25%)	3 (15%)
Explanation for the comparison between the two changes in magnitude.	3 (15%)	8 (40%)	2 (10%)

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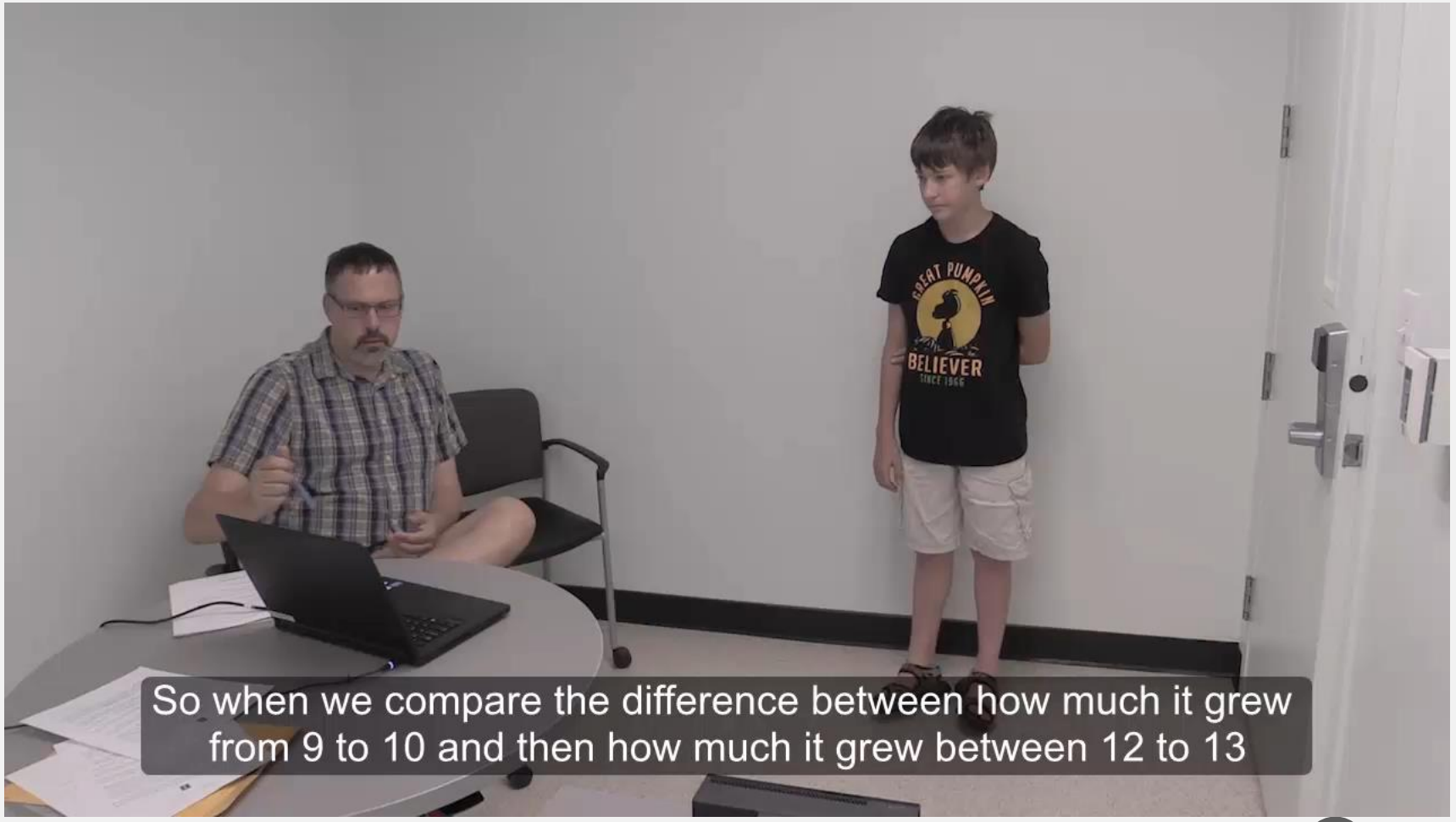
CONCEPTUALLY DRIVEN QUESTIONING: EMETT



MAINTAINING CONCEPTUAL FOCUS IN MULTIPLE CONTEXTS: IVY

Explicit attention was paid to the exponent as tasks changed.

Ivy worked on 4 calculation tasks. In sequence, they were:

1. numbers,
2. monetary amounts,
3. number of restaurants, and
4. population of algae

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OFFLOADING COMPUTATIONAL TASKS: ERIKA

POTENTIAL LEARNING IMPLICATIONS

- Conceptual questions helps learners attune to subtle ideas depicted within the simulation, which leverages tacit understandings of growth.
- While physical engagement with the simulation links core ideas across contexts, scaffolding across multiple contexts by the interviewer amplifies this effect.
- When learners become proficient using the simulation, they can offload complex computations to engage with deeper conceptual issues.

PROJECT INFORMATION

ELASTICS

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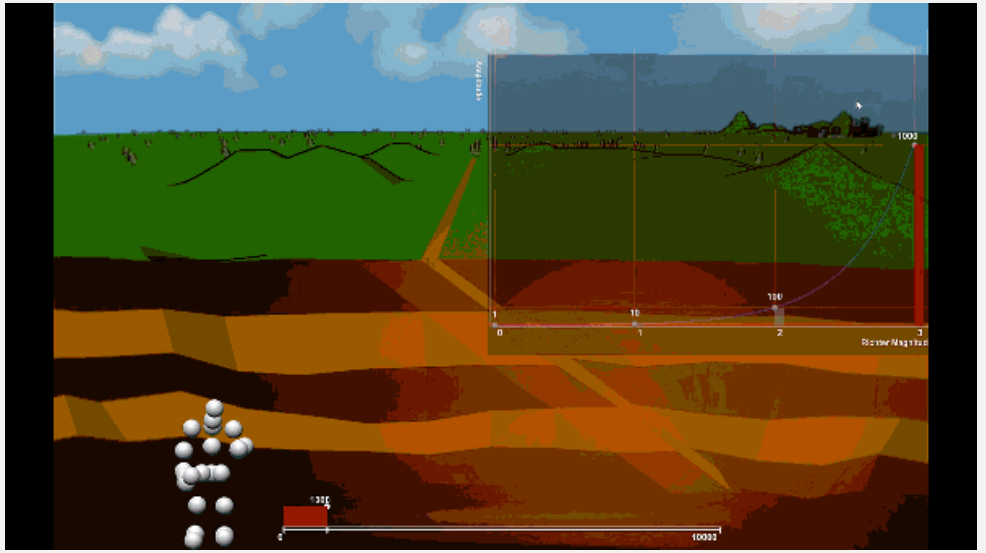

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