Large-Scale Research on Engineering Design Based on Big Learner Data Logged by a CAD Tool

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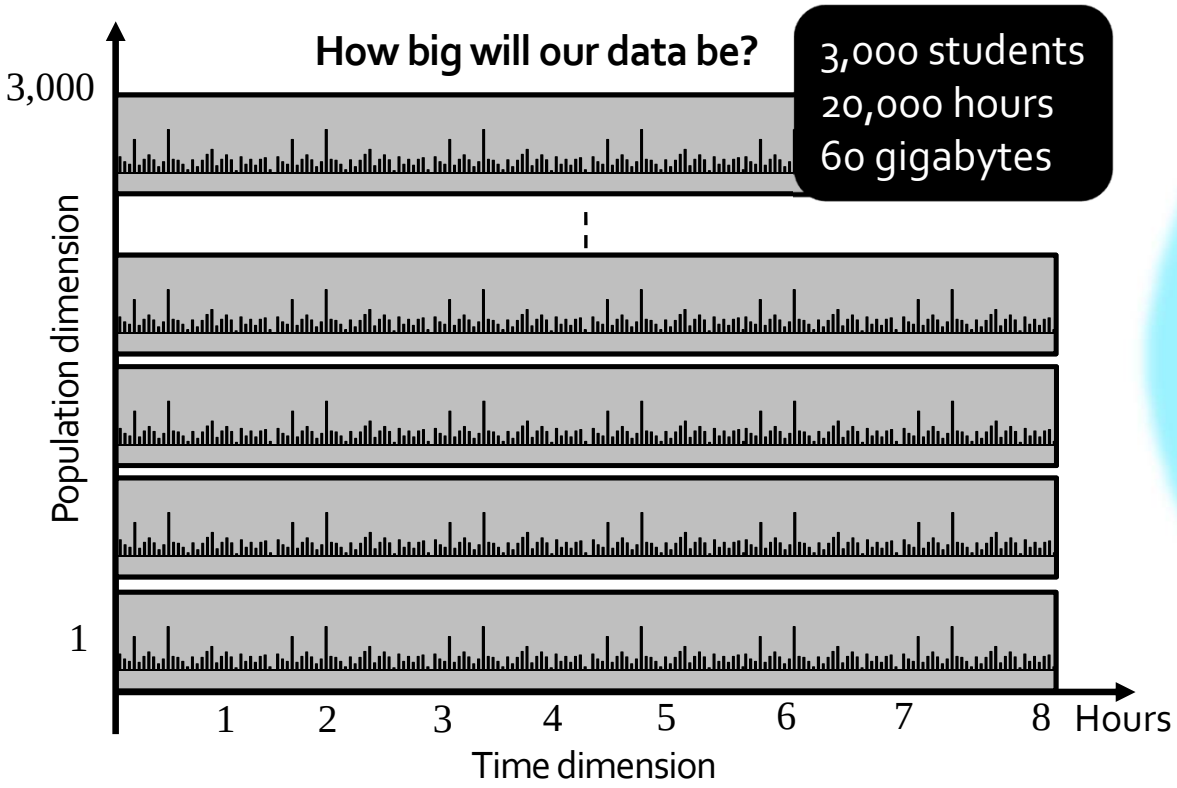
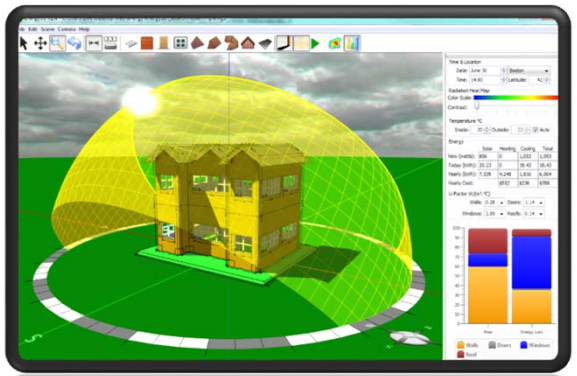


Three types of structured data streams
that record all student actions, artifacts, & articulations (AAA)

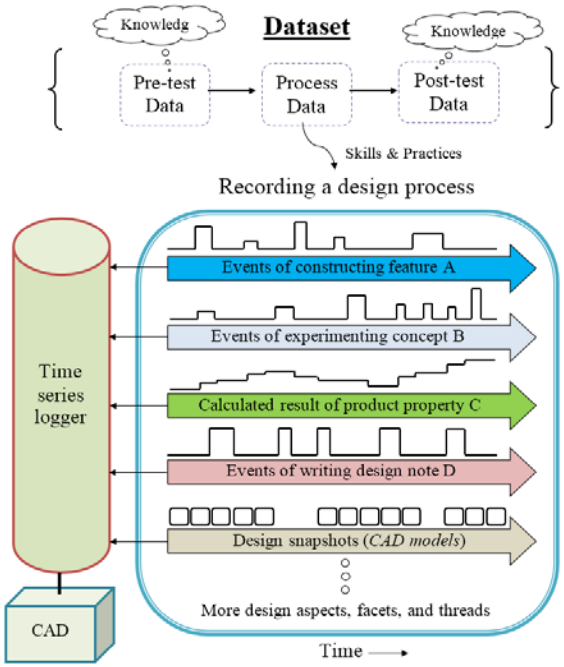
- How will we collect these data?
- What will we do with these data?
- What will we find from these data?

How will we collect these data?

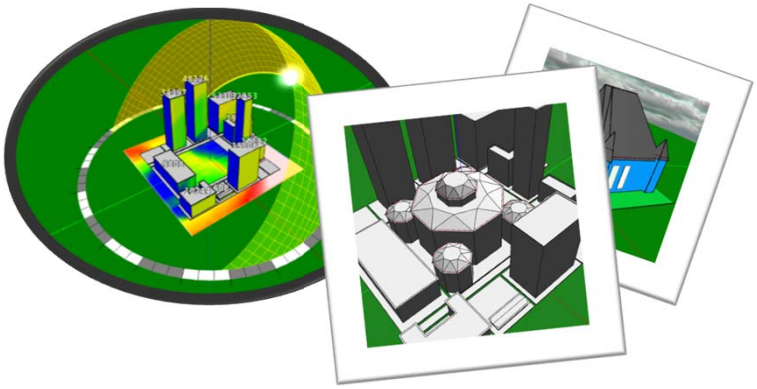
Energy3D: The ONLY computer-aided design (CAD) software that logs "atomically" fine-grained process data about what students do, make, and say — behind the scenes.

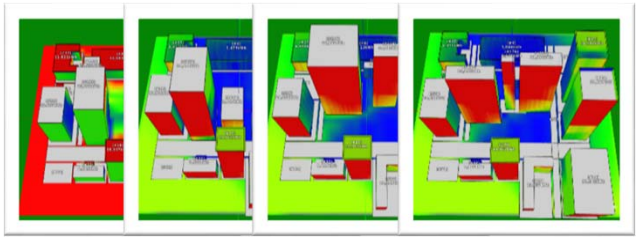


"A Big Data Microscope"



Testbeds: Solar Urban Planning, etc.





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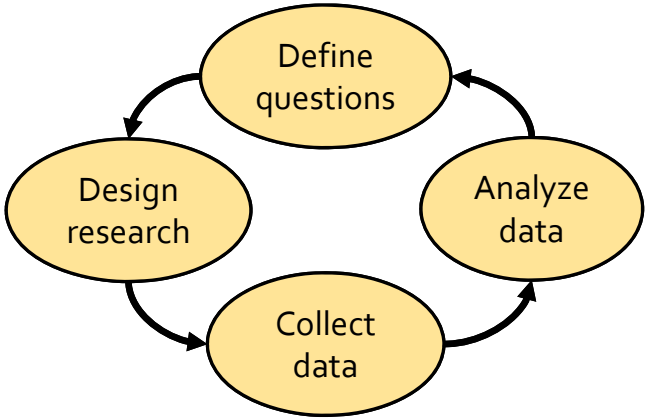
STEM areas:
Geometry, energy, thermodynamics, heat transfer, architectural engineering, building science, renewable energy, sustainability, … (NGSS MS-PS3-3/4 and HS-PS3-1/3/4)

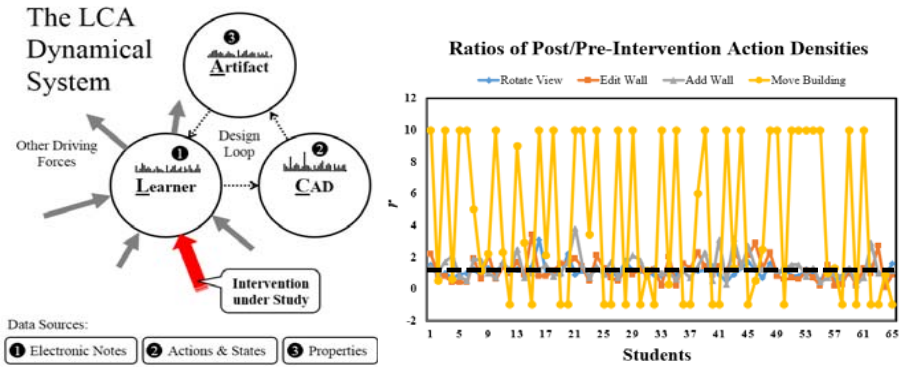
To probe how students learn in great details, we must build educational versions of "large hadron colliders!"

What will we do with these data?

Data are "mind recorders":
Use data as METHODS, not just OUTCOMES!



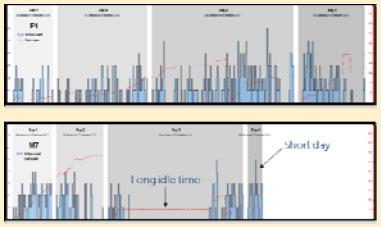
Computer logs are instructionally sensitive!



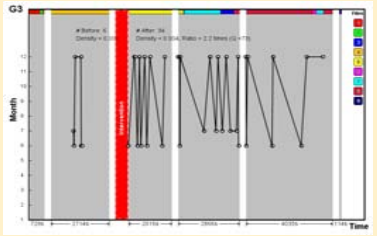
Learning dynamics visualization: Complete reconstruction and visualization of engineering design processes

- Time series analysis
- Signal processing
- Pattern recognition
- Machine learning

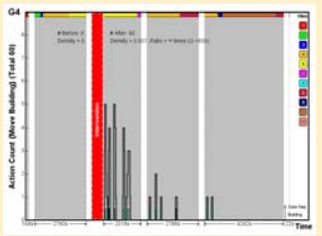
(4,000-6,000 actions
300-500 artifacts, &
500-1,000 words per student)



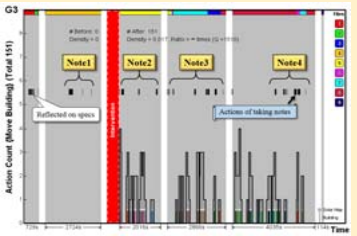
Activity



Iteration



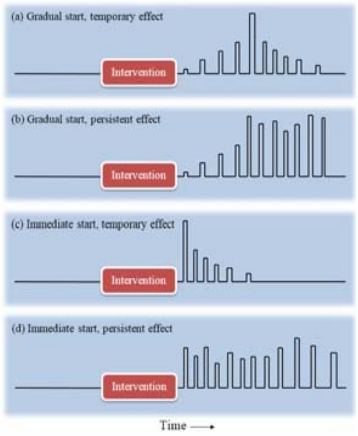
Decay



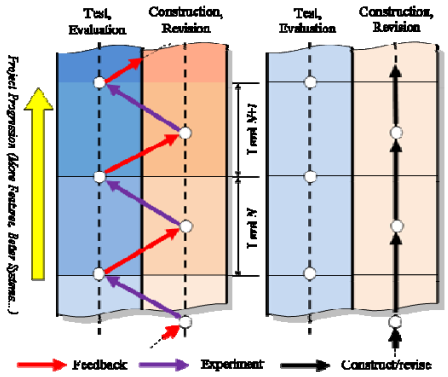
Alignment

What will we find from these data?

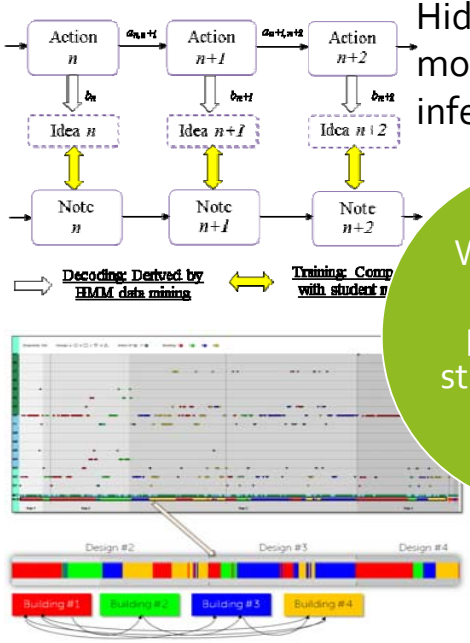
- What are learning trajectories and patterns that characterize iterative design, problem space exploration, convergent-divergent thinking, creativity, novice-expert transition, gender differences, etc.?
- What are the bottlenecks that block knowledge and skill transfer? What makes it difficult for students to learn and apply science concepts in engineering design projects (Vattam & Kolodner's "design-science gap")?
- What are the "chemical reactions" and "phase change" in learning dynamics? How do we find evidence of them from data? How do we engineer those cognitive processes pedagogically (and test it)?



Response functions



Science-engineering coupling and transfer



Hidden Markov modeling for inference

Iterative patterns

What are the **common patterns** of student design behaviors?

How are these patterns **associated with** prior knowledge, performance, learning, demographics?

How do students deepen their **understanding of science** concepts through engineering design?

How often do students use scientific experimentation to **make a design decision**?

A HUGE array of questions to ask and explore!