Creating and Experimenting with Models

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What will we do today?

• Learn a bit about the project
• Engage in developing a model

Learning Goals for Today:
You will be able to:
1) Explain how to support students in constructing models
2) Develop a model to explain an important scientific phenomenon.
Building Models Projects

Goals of the project
1. Develop a dynamic modeling tool (SageModeler)
2. Develop curriculum materials that align with the tool and goal from the NGSS
3. Study the affects of the tool on students developing understanding of various performance expectations

Collaboration between CREATE for STEM at MSU and the Concord Consortium (Dan Damelin)
What is really different about the Framework and NGSS?

1. Focus on explaining phenomena or designing solutions to problems

2. 3-Dimensional Learning
   1. Organized around disciplinary core explanatory ideas
   2. Central role of scientific and engineering practices
   3. Use of crosscutting concepts

3. Instruction builds towards performance expectations

4. Coherence: building and applying ideas across time
Science and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations and designing solutions
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

The practices work together – they are not separated!
What’s the value of scientific practices?

- Practices shift the focus from science classrooms as an environment where students learn about science ideas to places where students explore, examine and use science ideas to explain how and why phenomena occur.

- Science instruction should focus on figuring out how phenomena work!
What is a model?? What is modeling?

Take a few minutes a talk with the people at your table to respond to the following questions:

- What is a model?
- What does it mean to develop a model?
Our dream: engaging students in constructing models throughout the K – 12 curriculum

Students of all ages and backgrounds can take part in modeling!

Greater sophistication

<table>
<thead>
<tr>
<th>Grades K - 2</th>
<th>Grades 3 - 5</th>
<th>Middle School</th>
<th>High School</th>
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</thead>
<tbody>
<tr>
<td>Develop a simple model that represents a proposed object or tool.</td>
<td>Develop and revise models collaboratively to measure and explain frequent and regular events.</td>
<td>Develop models to describe unobservable mechanisms.</td>
<td>Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.</td>
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Developing and using scientific models

- A scientific model...
  - ...represents the objects and the relationships among them to explain and predict phenomena
  - ...provides a causal mechanism that accounts for the phenomenon
  - ...could be depicted as a drawing, diagram, 3-D, or other representation
  - ...but only representations that explain and predict phenomena are scientific models

Models explain or predict **how** and **why** phenomena happen
Steps in developing a model

• Plan: What objects do you need in your model? What factors or variables are associated with each of the objects?

• Build: What relationships exists between each of the factors/variables?

• Test: Do the set of relationships you developed, provide a causal account (i.e., does it explain the phenomena? does it account for all the evidence?)?

• Revise: Does your model still provide a causal account for any new evidence or other phenomena? How should it be changed?
Let’s build a model

Go to the Concord Home page, select projects and look for Building Models Project

http://concord.org/projects/building-models#about
Status of Project

- You can use the current version but be aware that there are still bugs
- Curriculum materials
  - Middle school unit on carbon cycling – final stages of development
  - High School units – start development
- New features:
  - Quantitative mode
  - Data entry mode
- Field testing will begin at the end of February
  - Two middle grade classrooms
  - Two high school classrooms
Questions?

• What questions do you have regarding modeling?
• Other questions:

Email Addresses

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Partners

Funder

Institute for Collaborative Research in Education, Assessment, and Teaching Environments for STEM
The LEONARDO Project: Virtual Science Notebooks and Science Modeling for Upper-Elementary Science Education

James C. Lester     Robert G. Taylor

North Carolina State University
Transforming education with next-generation learning technologies

• NAE Grand Challenge for Engineering: Advanced Personalized Learning

• Mission: Design, deploy, and investigate adaptive learning environments
One-on-One Tutoring
“Provide a teacher for every learner”

- Learn at their own pace and in their own style
- Receive continuous, customized and meaningful feedback and assessment
- Acquire new skills in a way that is compelling and engaging
Design Challenge

“... provide learning environments that approach the effectiveness of one teacher for every learner. Such systems, properly used, can produce a significantly better-educated populace by combining advances in learning sciences with advances in information technology.”
Personalized Learning Technologies
Intelligent Tutoring Systems

- Communication Module
- Domain Knowledge
- Student Model
- Pedagogical Planner
What’s Right with This Picture?

- Student modeling
- Pedagogical planning
- Adaptive feedback

Cognitive effectiveness
What’s Wrong with This Picture?

- Does not feature science modeling
- Inquiry not playing a central role
- Missing key benefits of science notebooks
- Engagement not key design objective

Rich inquiry + lab-based science + engagement
Personalized Learning Hypothesis

Interactive Modeling + Pedagogical Agents

Motivational Support

Growth Mindset

Interest

Persistence

Learning

Cognitive Support
The LEONARDO Project

- Intelligent science notebook
- Guided inquiry-based learning
- Upper elementary science education
- Diagrammatic interactive modeling
- Multi-platform delivery
  - Tablet
  - Web browser
Diagramming in Science Education

Drawing is central to thinking and learning about science [Ainsworth et al., 2010]:

- Improve sense-making
- Communicate knowledge
- Reveal understanding
Drawing in Science Education
Mining Learner-Generated Science Drawings

Student Drawings

Diagrammatic Student Model

- Personalized Scaffolding
- Formative Assessments
- Misconception Identification
- Knowledge Modeling
The LEONARDO Project

- Interactive modeling
- Pedagogical agent
- Curriculum:
  - Energy & Circuits
  - Magnetism
- NGSS aligned
- FOSS compatible
The word energy means the ability to do work make things move or happen it comes in different forms such as heat light motion chemical and electrical.

What can energy be used for?
Energy can be used for tv phones computers and tabalats phone wires the building that runs off of

Where does energy come from?
Energy comes from a d-cell souces
Modeling via Drawing

- Students draw with semantically grounded objects
- Mitigates cognitive load issues
- Preserves generative nature of drawing
Automating Drawing Assessment

- Student-generated drawing
  - Collection of graphical elements
  - 2D coordinates for each element
  - Orientation for each element

- Automatically analyze drawings
  - Scored with respect to normative models
  - Considers extraneous elements, missing elements, spatial relationships, and domain specific relationships
Computational Challenges

- Large solution space
  - Multiple families of correct drawings
  - Majority of space comprised of incorrect drawings

- Broad range of drawing quality
  - Conceptual variance
  - “Execution” variance
Computational Challenges

- **Large solution space**
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- **Broad range of drawing quality**
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Topological Representation

Labeled Graph Encoding

- Nodes represent key graphical elements
- Edges represent topographical relations
- Capable of representing broad array of relations between objects

Drawing Elements → Domain Model
- Domain Features
- Spatial Features → Topology Graph
Topology: Elements
Topology: Connectivity
Middle School Microbiology & Literacy - Free!

http://projects.intellimimedia.ncsu.edu/crystalisland/

cei-contact@ncsu.edu
Download Information - Free!

https://projects.intellimedia.ncsu.edu/leonardo/

cei-contact@ncsu.edu
Challenges of Adaptive Learning Environment Authoring

- Authors who are not computer scientists
- Enabling collaboration
- Reducing the learning technology complexity exposed to authors
Scalable Authoring Tools

- Design principles derived from our experience
- Adopting existing UI and workflows
- Leveraging software engineering techniques
LEONARDO Authoring

- To date has enable SMEs to author:
  - Energy & Circuits
  - Magnetism
- Pedagogical agent
  - Behaviors
  - Advice (TTS built in to LEONARDO)
For a flashlight to work, it needs to have two things. It needs to have batteries and a light bulb. They each have their jobs to do. Which one of them provides energy to run the flashlight, and which one changes the energy into light?

This is a static text entry. Replace this text with your own text.

A <select> provides the energy to run a flashlight.

A □ changes energy into light.

Replace this text with instructions for an essay question.
Authors use Composer to create:

- Curricular content
- Agent dialogue
- Agent behavior
Prior to Composer

Original authoring workflow:

- Word used to author curriculum and agent dialogue
- Doc copied into XML
- XML embedded in the iPad app
- Agent behavior authored in code by software engineers
Prior to Composer

Drawbacks:

- 15+ minute iteration
- Lack of WYSIWYG
- “Collaboration” by e-mailing Word docs
- Prone to programmer error
- Rules authored in source code
Lesson Learned: Create an Authoring Tool

- Identify authors:
  - STEM SMEs
  - K-12 teachers (future)
- Identify familiar tools
- Design Composer based on familiar UIs & features
- Iteratively develop Composer based on author feedback

Edmodo  Google Docs  PowerPoint
LEONARDO Architecture
Prior to Composer

CyberPad
Curricular Content
Pedagogical Rules

Cloud-based Server
Student Data

Person

CyberPad
Curricular Content
Pedagogical Rules

...
LEONARDO Architecture with Composer

Cloud-based Server

- Curricular Content
- Pedagogical Rules
- Student Data

CyberPad

Composer

Composer
Composer Features

- Simplified workflow
- Familiar UI
- Rapid iteration
- Curricular content stored in cloud
- Web-based authoring tool
Principle 1: Familiar User Interface Paradigm

- UI is the most important feature
- Familiar to author
- Leverage decades of usability and efficiency improvements
Principle 2: Standard Editing Features

- Relied upon by authors
  - Copy, Cut, and Paste
  - Undo and Redo
  - Revision Tracking

- Can profoundly affect curricular content storage

- Should not be left as a feature to be added at the end of project
Principle 3: Author Collaboration

- Multiple author collaboration
- Facilitates communities of authors
- Increase both quality and quantity of content
Principle 4: Rapid Iteration

- WYSIWYG or live connection to the ITS
- Changes can be quickly seen in the context of the ITS
- Test ITS behavior while editing rules
Principle 5: Accommodate Novice and Expert Authors

- UI tailored to novice and expert users
- Wizard interfaces for novice users
- Advanced authoring UI for expert users
Principle 6: Automation

- Some tasks too labor intensive
- Provide automation for repetitive tasks
- Learning analytics to highlight curricular “hot spots”
Conclusion

- Intelligent virtual notebooks hold significant potential for next-gen science education.

- LEONARDO CyberPad supports sketch-based interactive modeling supported by a virtual agent.

- Authoring tools hold great promise for facilitating rapid creation of scalable solutions to adaptive cyberlearning environments.
Future Work

- Expanding to full suite of sketch recognition and sketch understanding functionalities.

- Apply learning analytics to identify interactions that will particularly benefit from adaptive scaffolding.

- Leveraging advanced student modeling capabilities featuring PAIR (plan, activity, and intent recognition) for optimizing personalization of inquiry activities and guidance.