Creating and Experimenting with Models

Joe Krajcik
CREATE for STEM
Michigan State University

CREATE for STEM Institute

The Concord Consortium

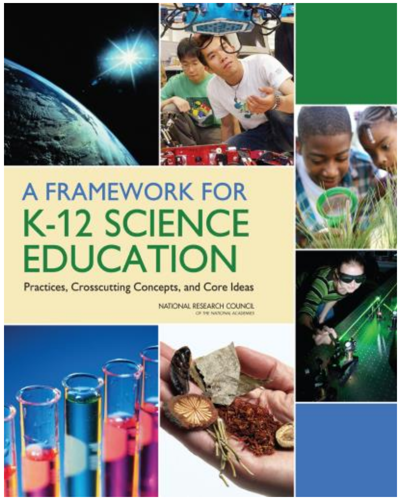
STEM Smart
February 1, 2016

STEM Smart workshops are funded by the National Science Foundation grant #1449550. Any opinions, findings, and conclusions or recommendations at this event or in these materials are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

NSF

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.

NEXT GENERATION SCIENCE STANDARDS

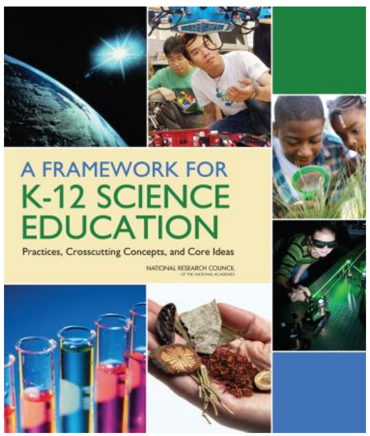
Building Models Projects

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?



NEXT GENERATION SCIENCE STANDARDS

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

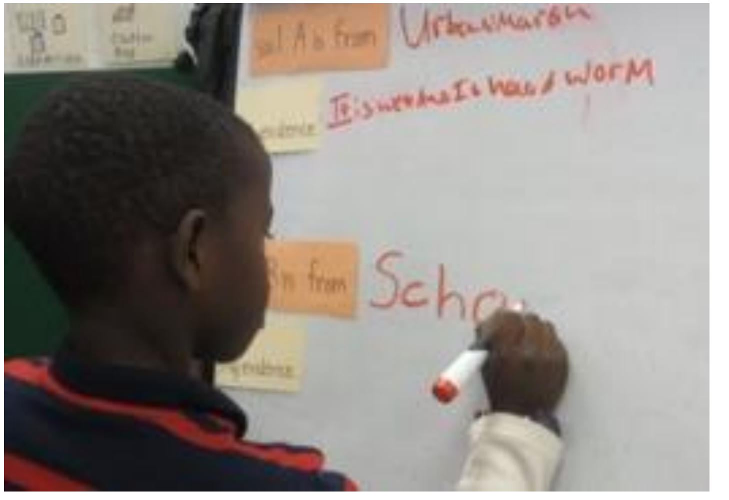
The multiple ways of knowing and doing that scientists and engineers use to study the natural world and design world.

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**

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 phe



- 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

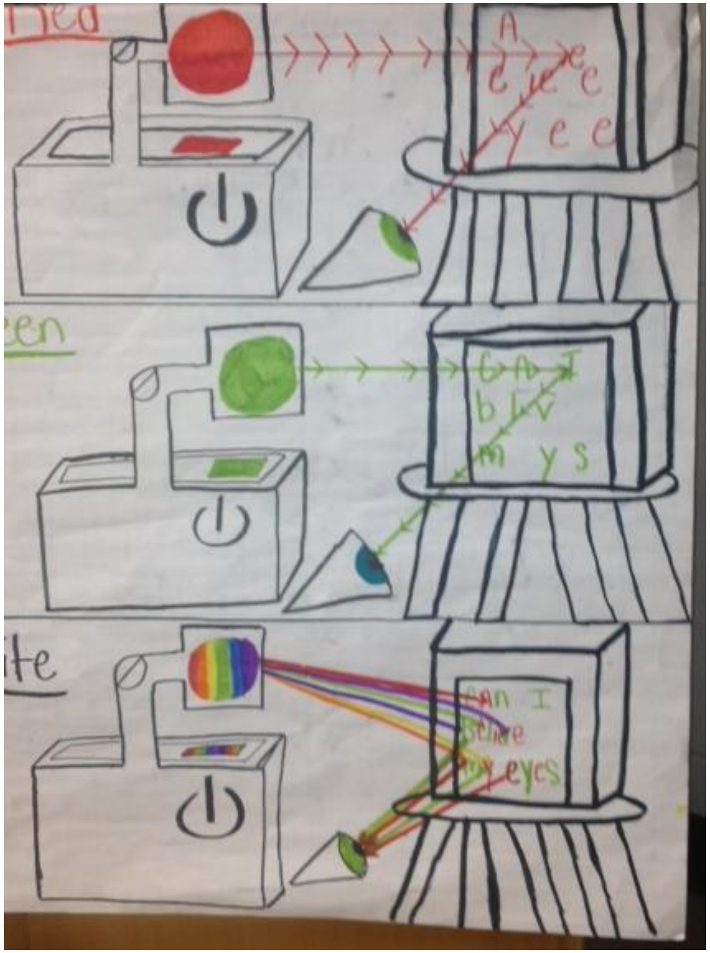
Students of all ages and backgrounds can take part in modeling!

Greater sophistication →

Grades K - 2	Grades 3 - 5	Middle School	High School
Develop a simple model that represents a proposed object or tool.	Develop and revise models collaboratively to measure and explain frequent and regular events.	Develop models to describe unobservable mechanisms.	Develop, revise, and use models to predict and support explanations of relationships between systems or between components of a system.

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

Joe: krajcik@msu.edu twitter: @krajcikjoe

Partners

CREATE for STEM Institute

The Concord Consortium

Funder

NSF

The LEONARDO Project:
Virtual Science Notebooks and Science Modeling for Upper-Elementary Science Education

James C. Lester   Robert G. Taylor

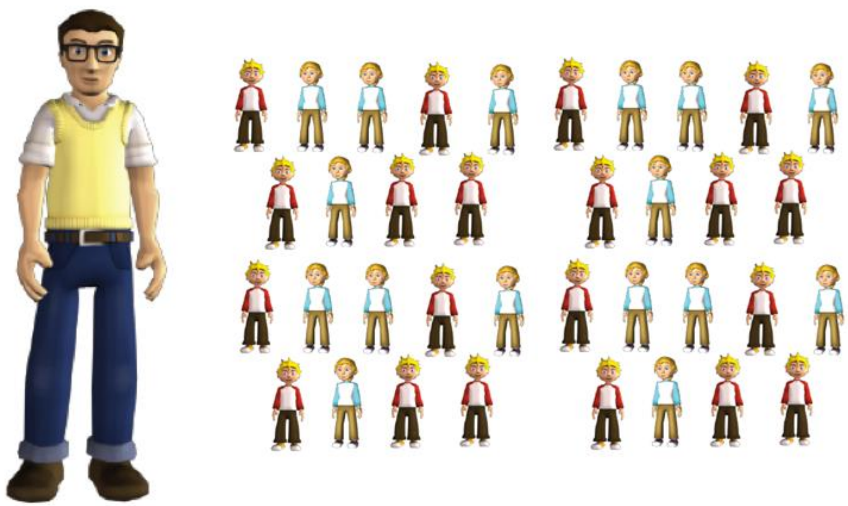
North Carolina State University

Center for Educational Informatics

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



Design Challenge

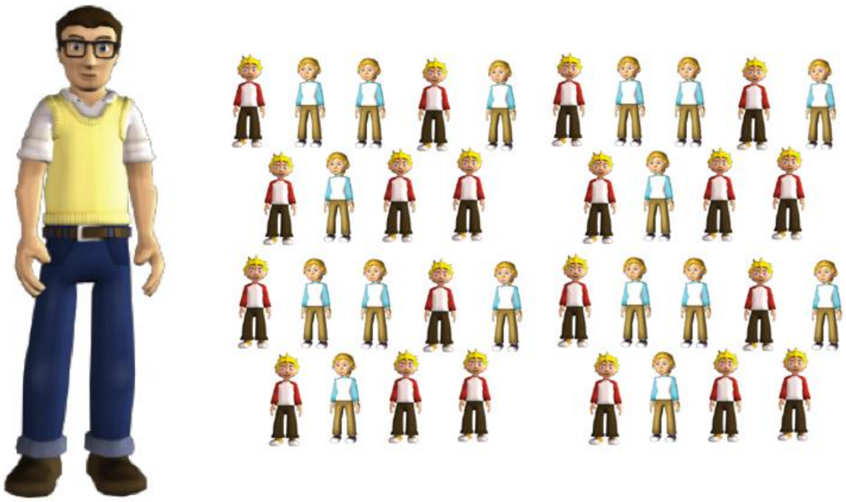
"Provide a teacher for every learner"

- 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

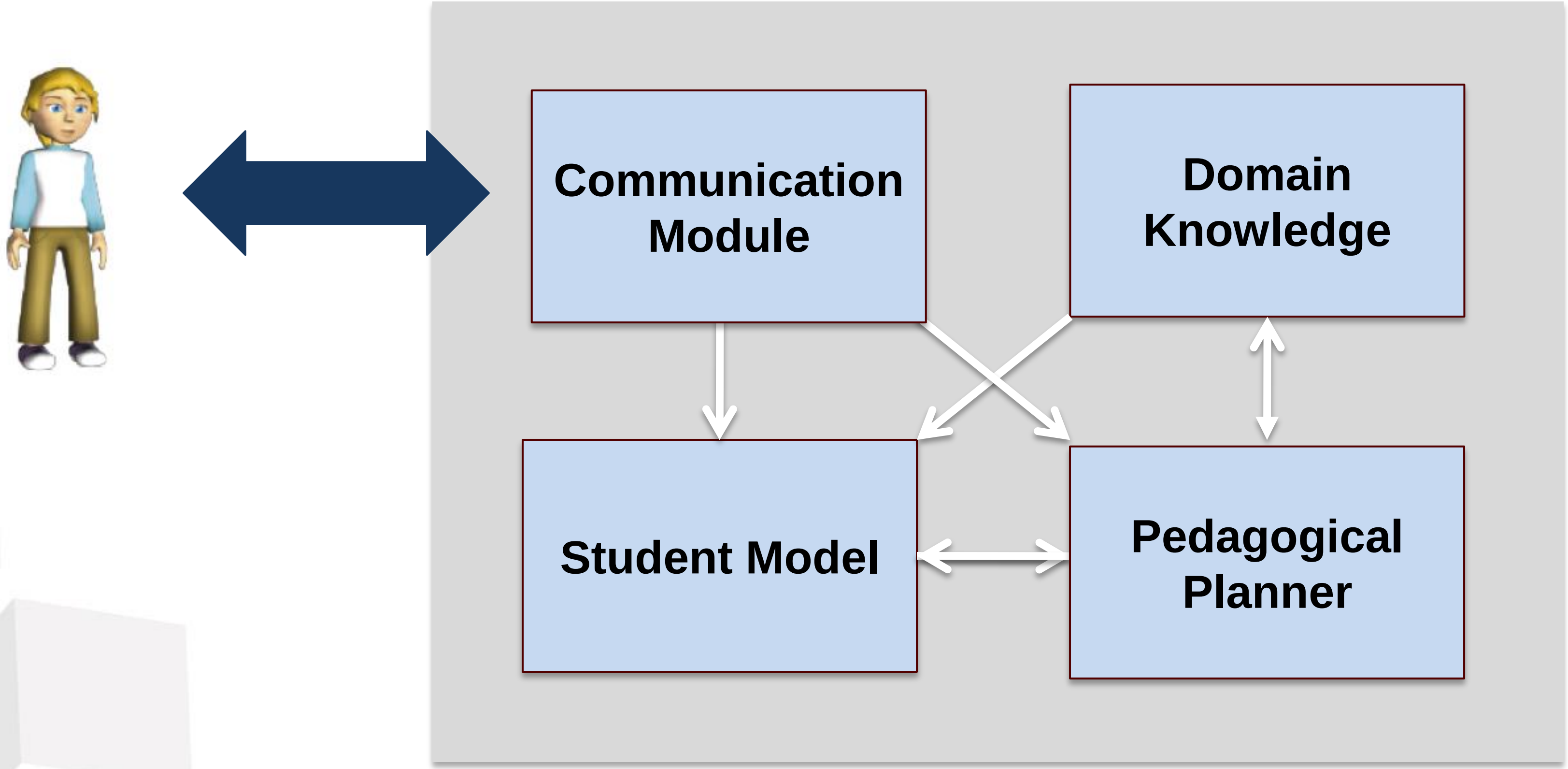
Design Challenge

"… 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



What's Right with This Picture?

- Student modeling
- Pedagogical planning
- Adaptive feedback

→ Cognitive effectiveness

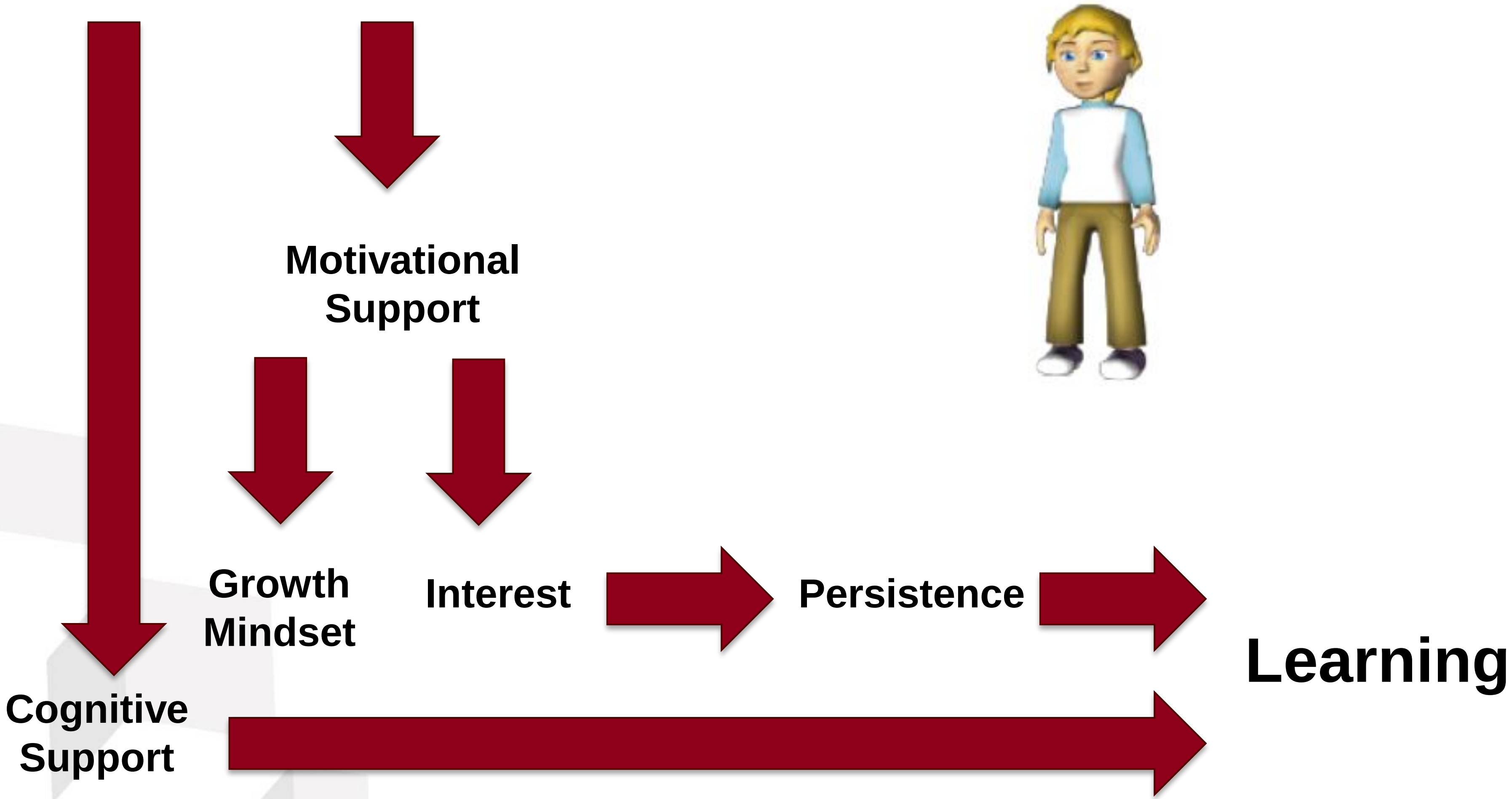
What's Wrong with This Picture?

- 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

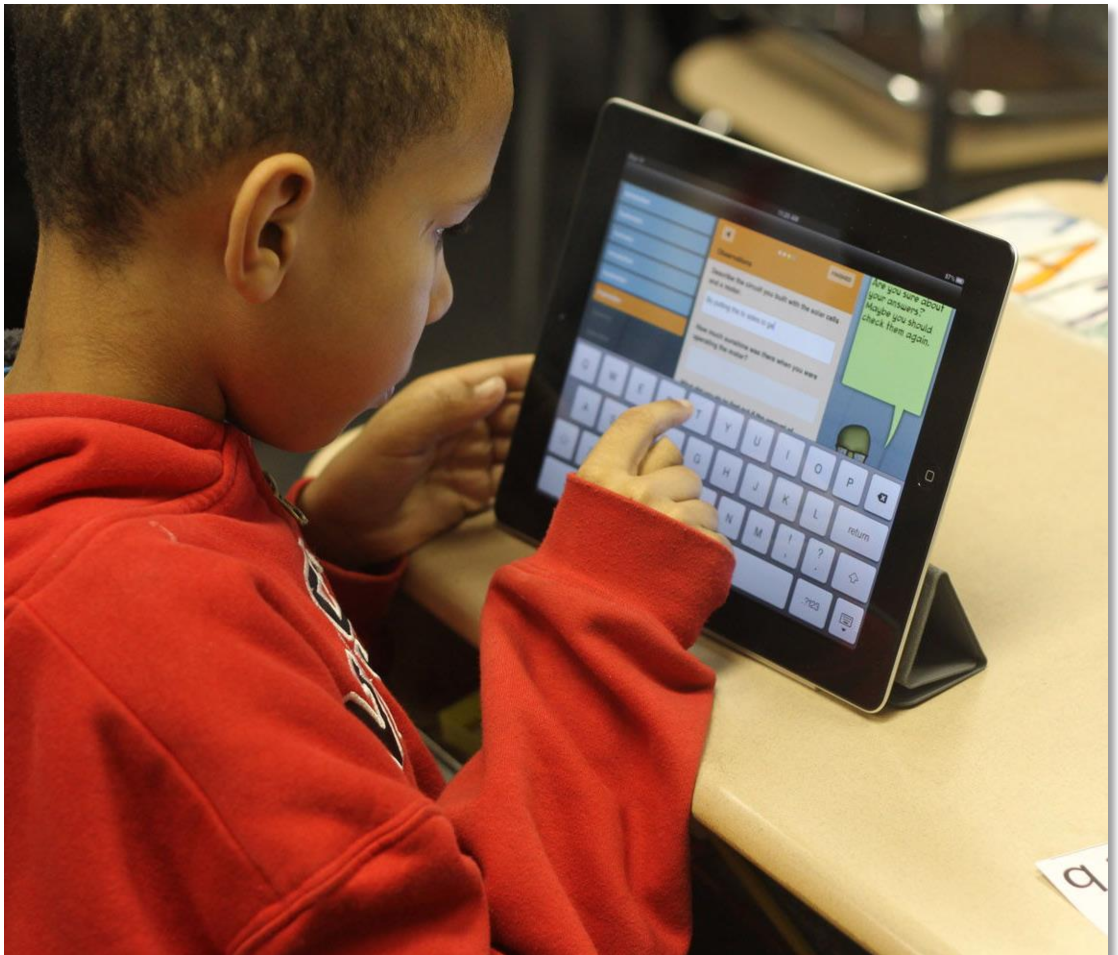
Personalized Learning Hypothesis

Interactive Modeling + Pedagogical Agents



The LEONARDO Project

the intelliMEDIA group

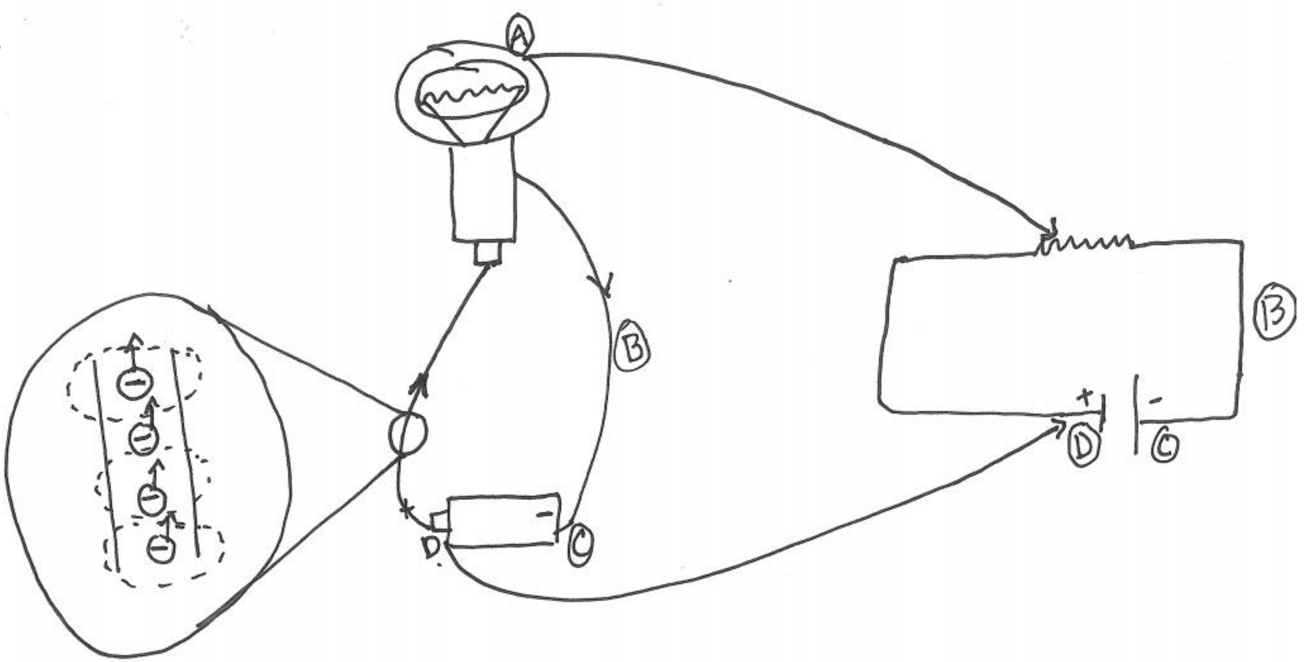


- Intelligent science notebook
- Guided inquiry-based learning
- Upper elementary science education
- Diagrammatic interactive modeling
- Multi-platform delivery
  - Tablet
  - Web browser

Diagramming in Science Education

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

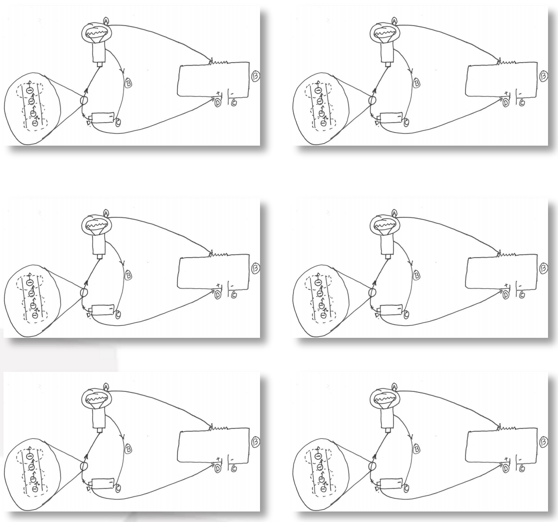
- Improve sense-making
- Communicate knowledge
- Reveal understanding



Drawing in Science Education

Mining Learner-Generated Science Drawings

Student Drawings



Diagrammatic Student Model

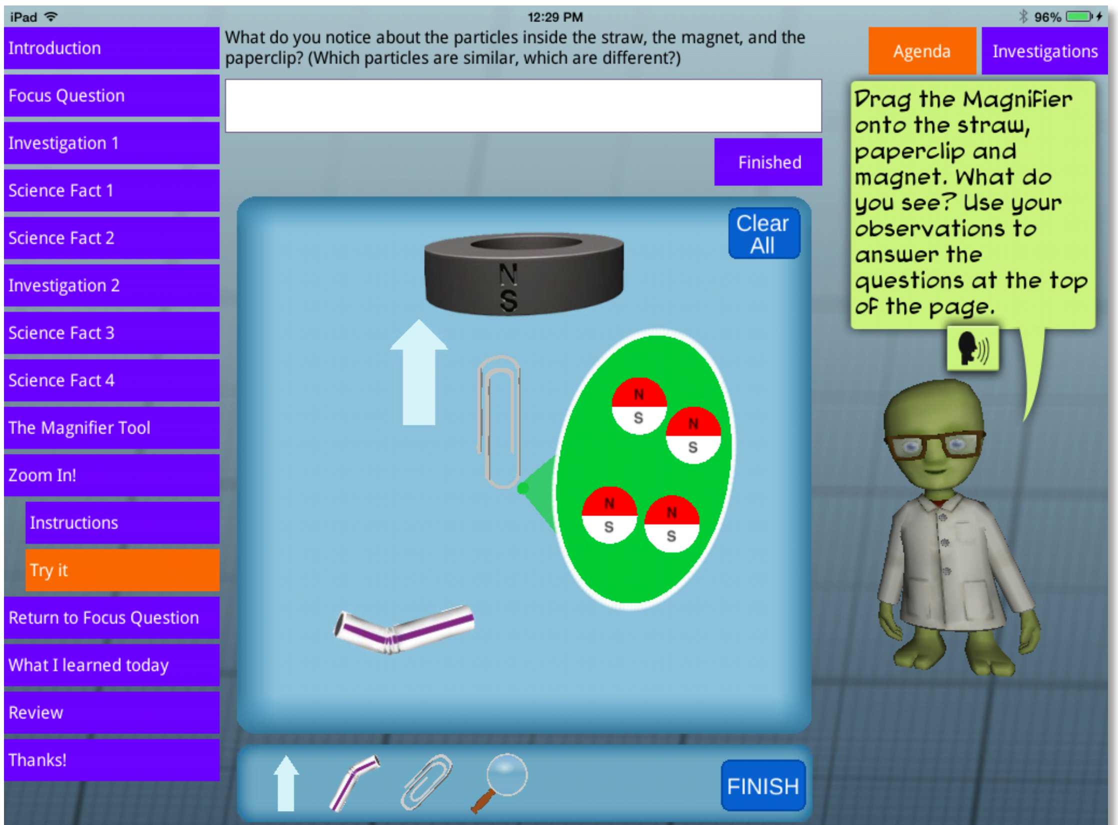
Personalized Scaffolding

Formative Assessments

Misconception Identification

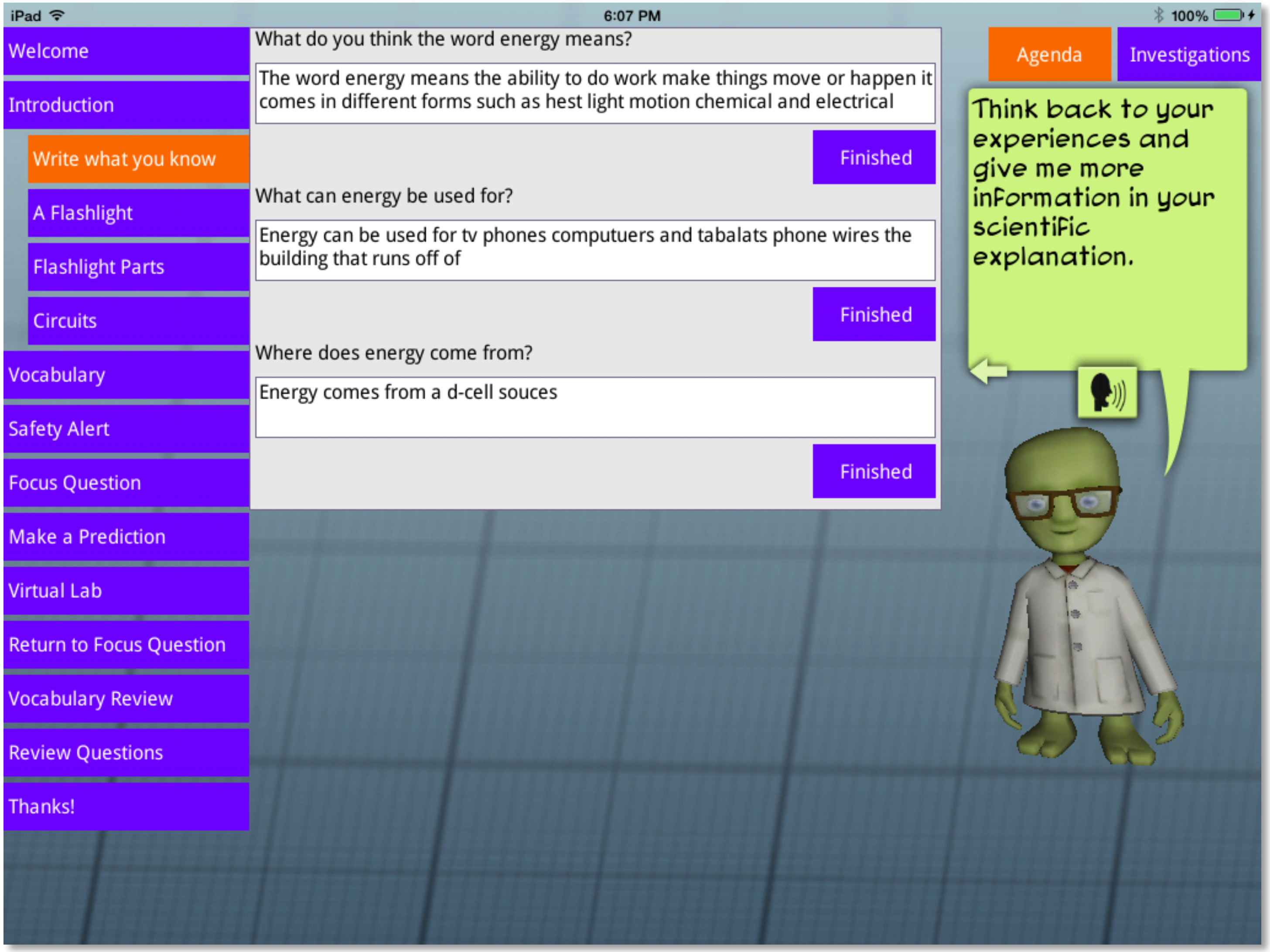
Knowledge Modeling

The LEONARDO Project



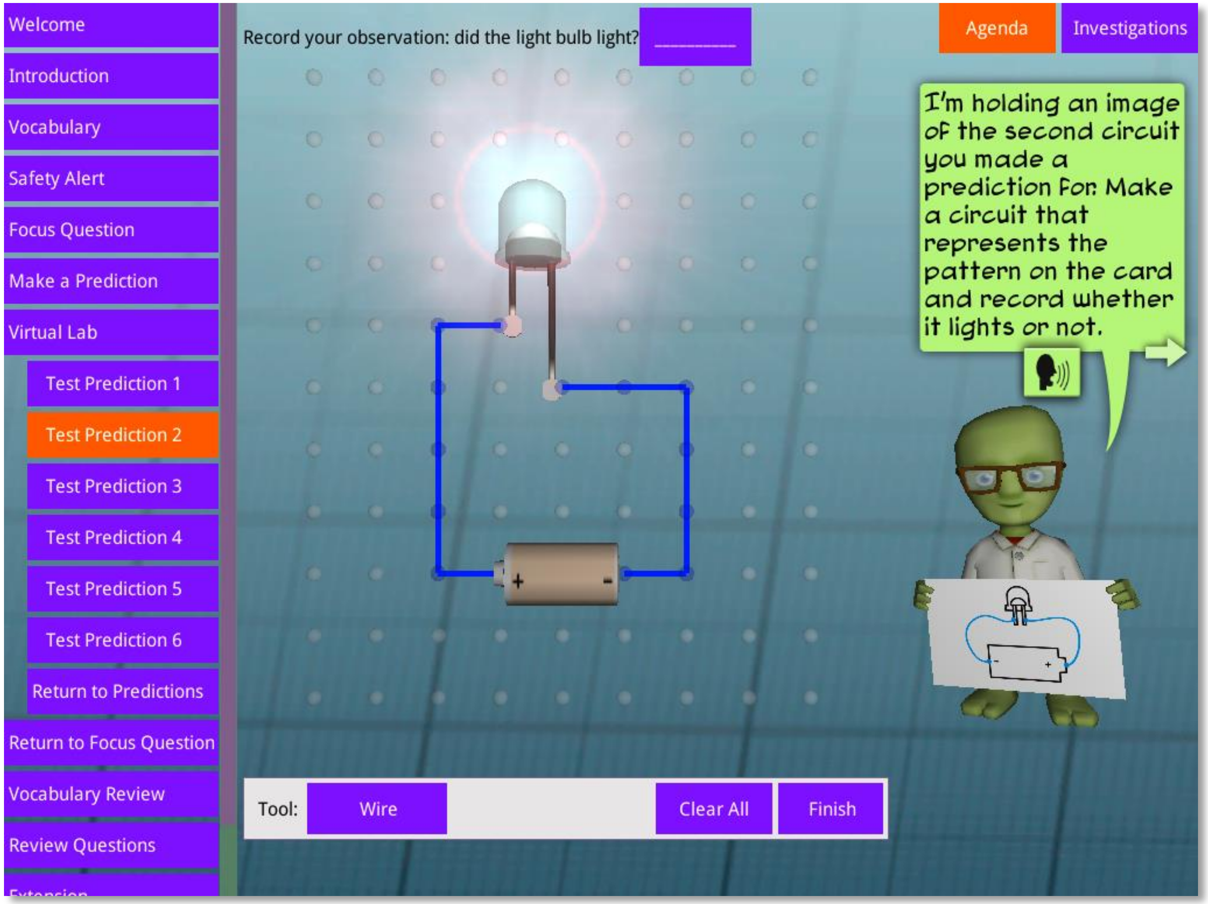
- Interactive modeling
- Pedagogical agent
- Curriculum:
  - Energy & Circuits
  - Magnetism
- NGSS aligned
- FOSS compatible

LEONARDO CyberPad



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

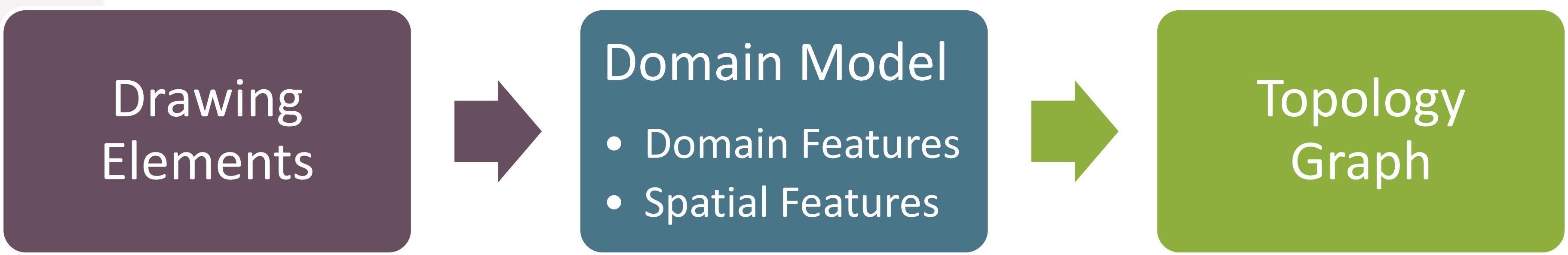
Computational Challenges

- Large solution space
  - Multiple families of correct drawings
  - Majority of space comprised of incorrect drawings
- Broad range of drawing quality
  - Conceptual variance
  - “Execution” variance

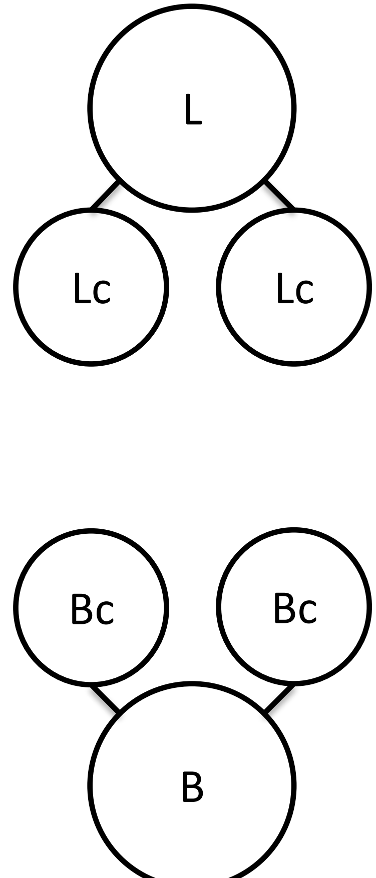
Topological Representation

Labeled Graph Encoding

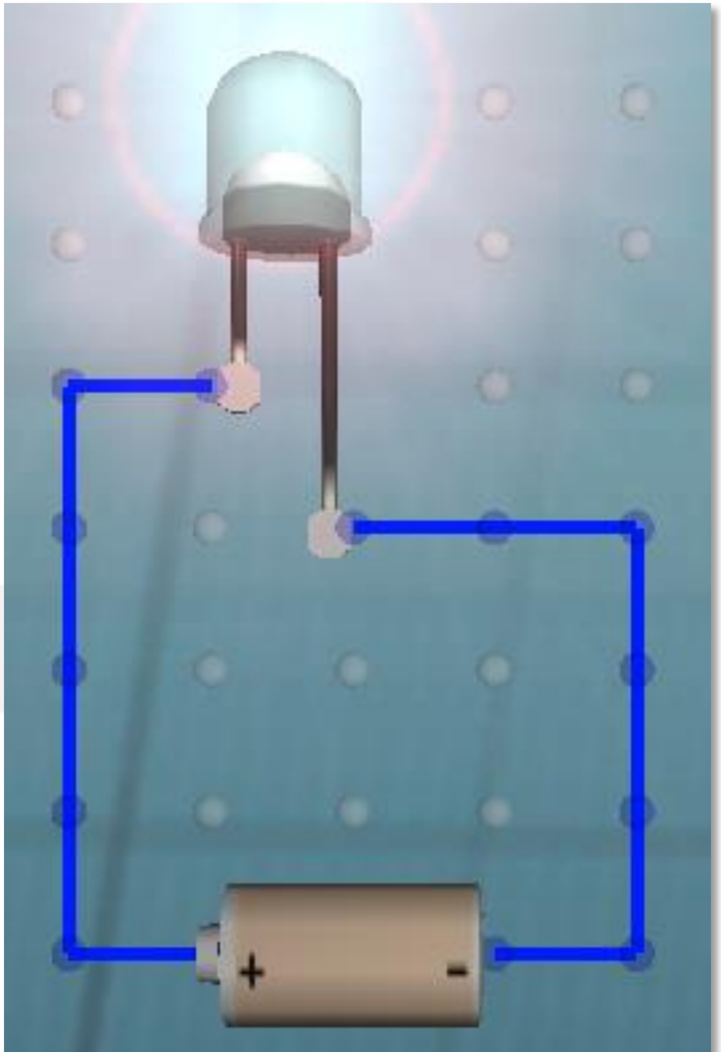
- Nodes represent key graphical elements
- Edges represent topographical relations
- Capable of representing broad array of relations between objects

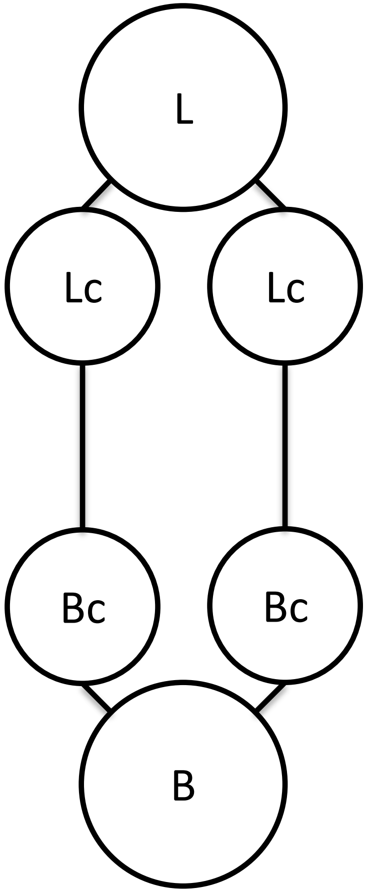


Topology: Elements

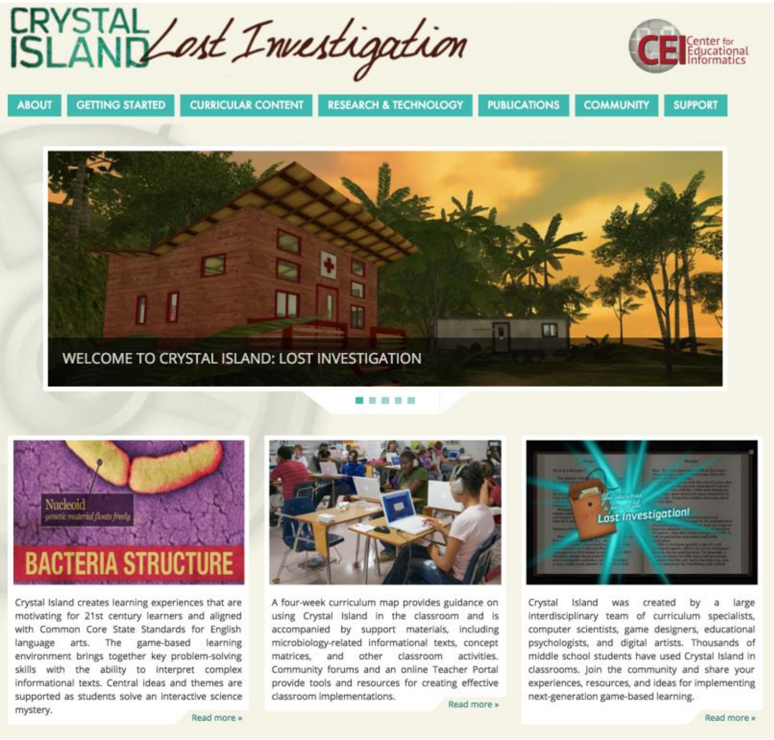


Topology: Connectivity





Middle School Microbiology & Literacy - Free!



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

cei-contact@ncsu.edu

Download Information - Free!

Download on the App Store

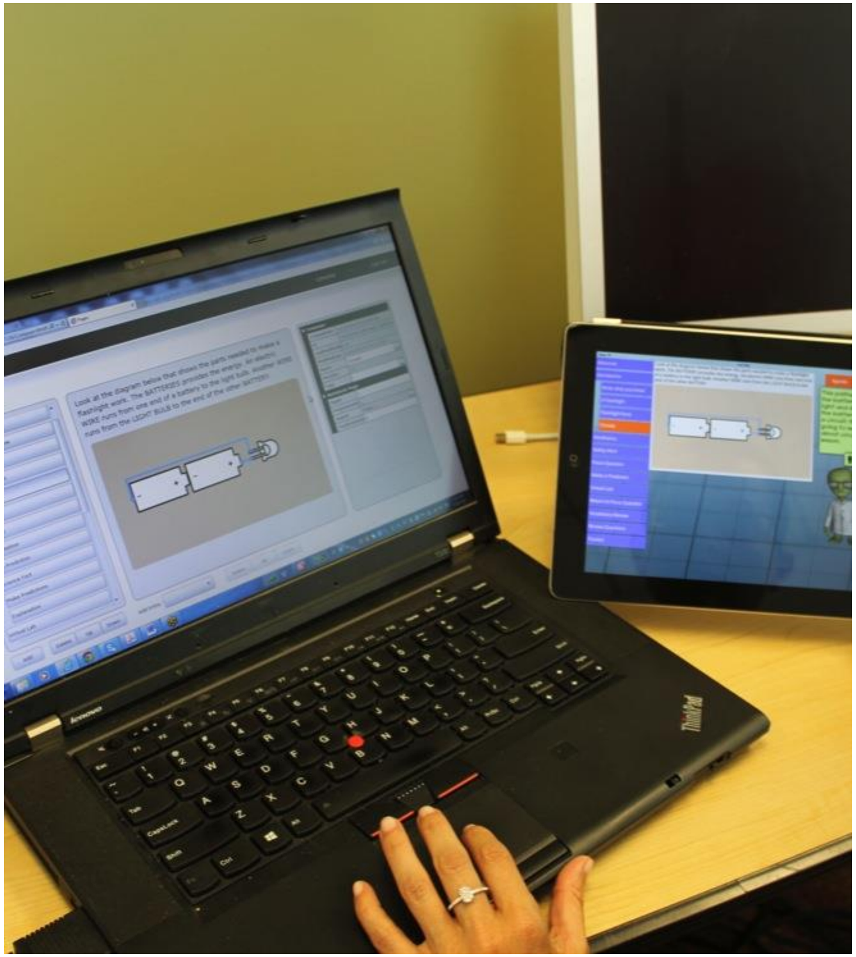
https://projects.intellimedia.ncsu.edu/leonardo/

cei-contact@ncsu.edu

LEONARDO CyberPad Laptop Demonstration

Challenges of Adaptive Learning Environment Authoring

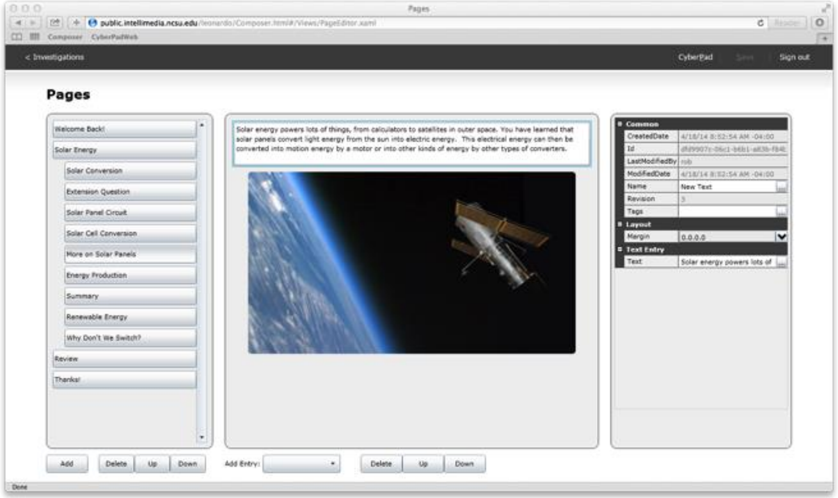
- Authors who are not computer scientists
- Enabling collaboration
- Reducing the learning technology complexity exposed to authors



Scalable Authoring Tools

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

Composer

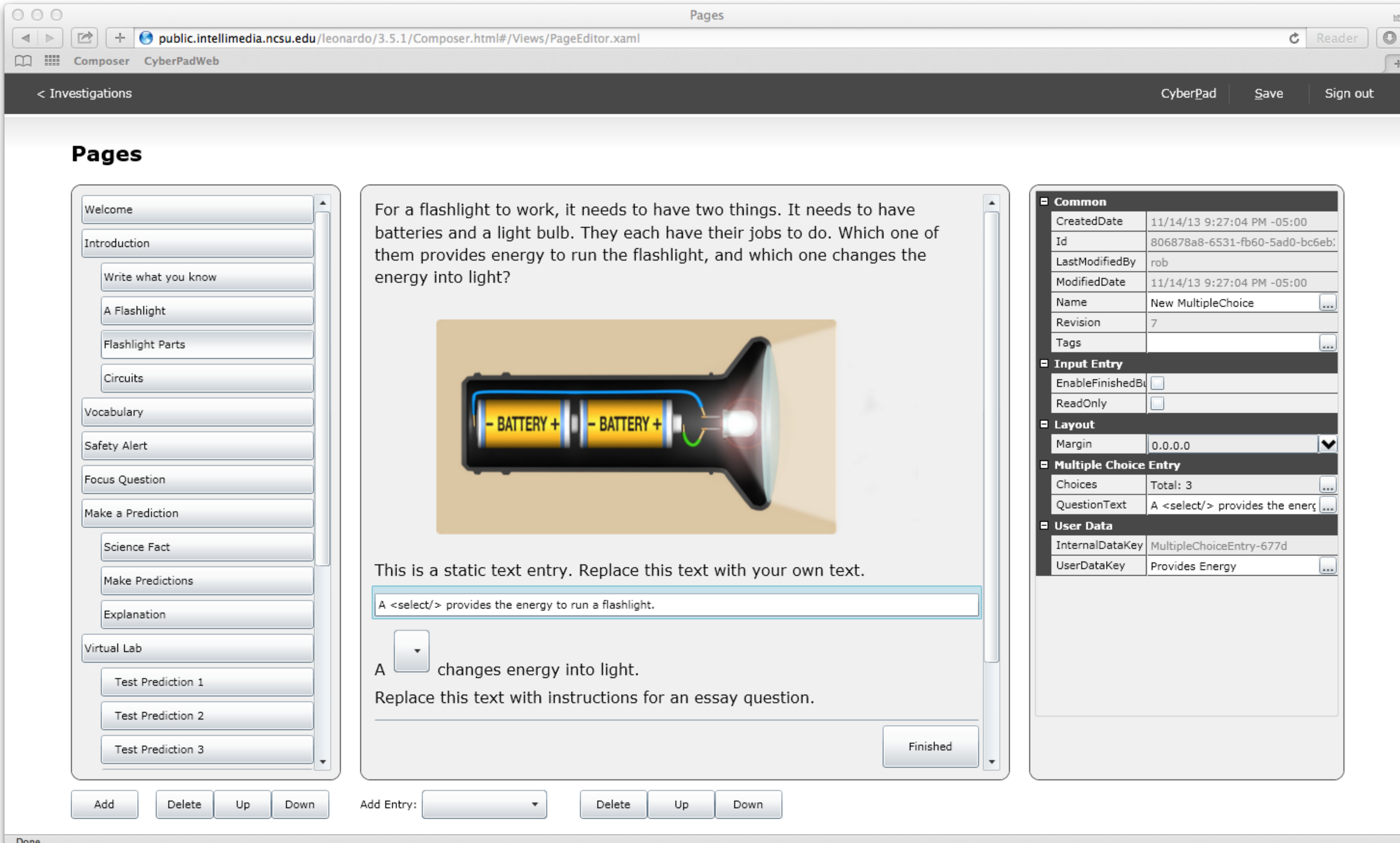


LEONARDO Authoring

- To date has enable SMEs to author:
  - Energy & Circuits
  - Magnetism
- Pedagogical agent
  - Behaviors
  - Advice (TTS built in to LEONARDO)

LEONARDO Composer

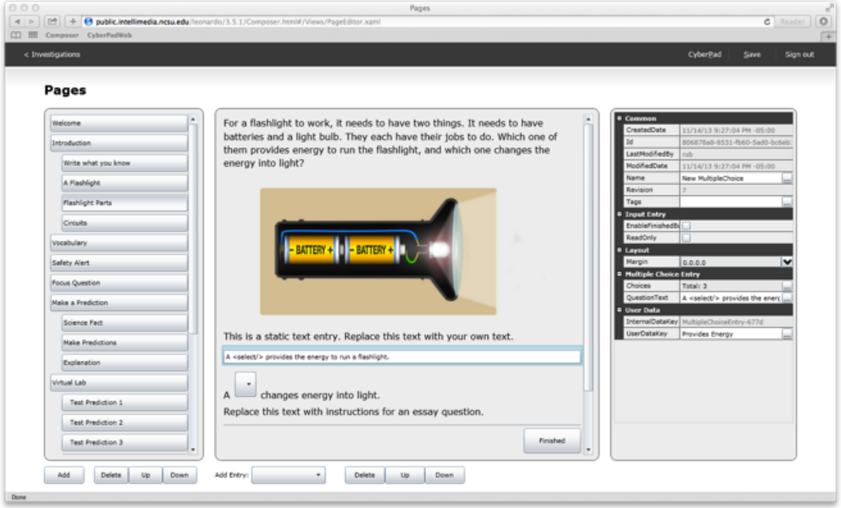
theintelliMEDIA group



LEONARDO Composer

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

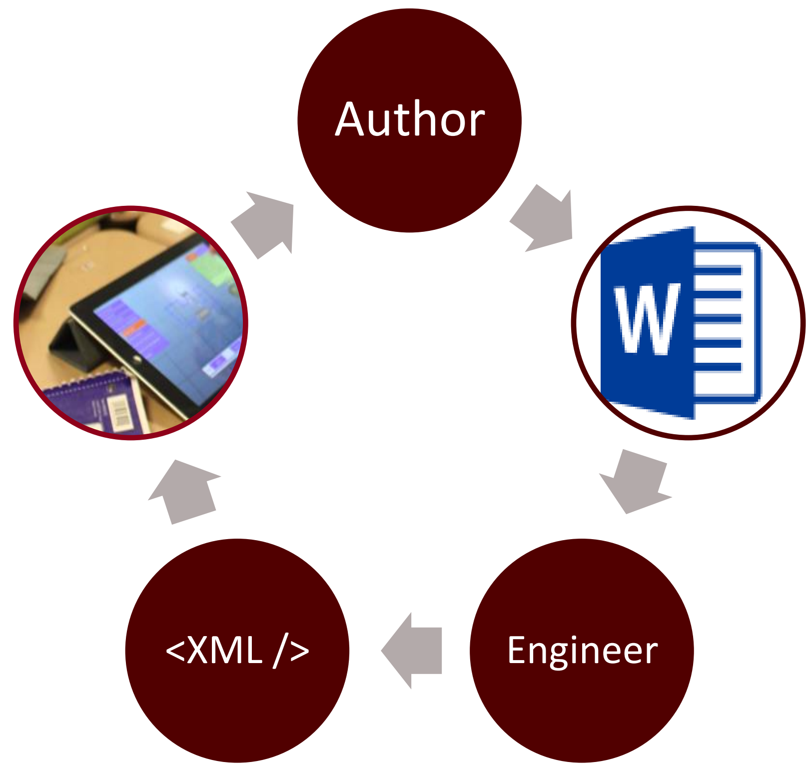
Word

<XML />

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

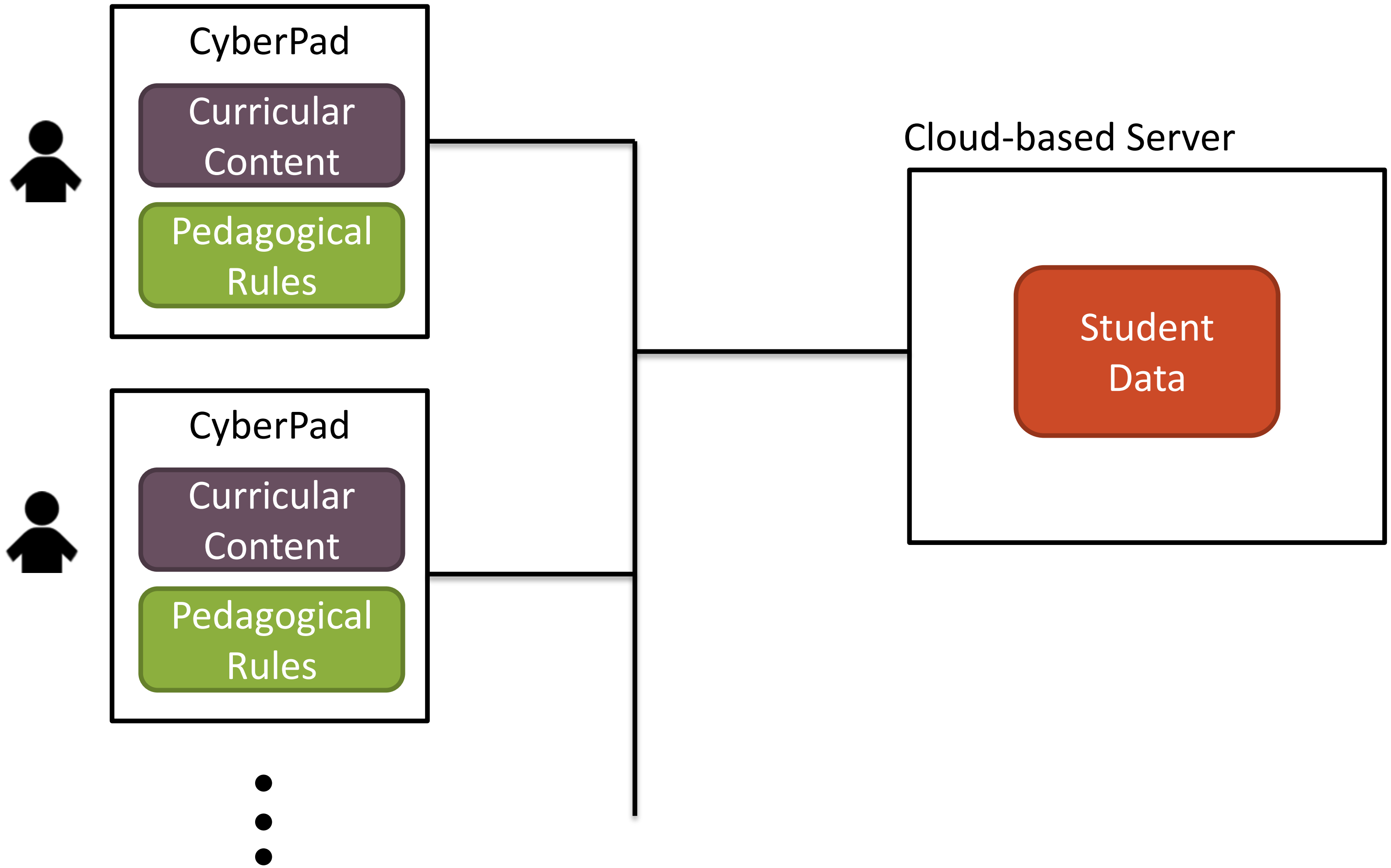
- Identify authors:
  - STEM SMEs
  - K-12 teachers (future)
- Identify familiar tools
- Design Composer based on familiar UIs & features
- Iteratively develop Composer based on author feedback

Edmodo

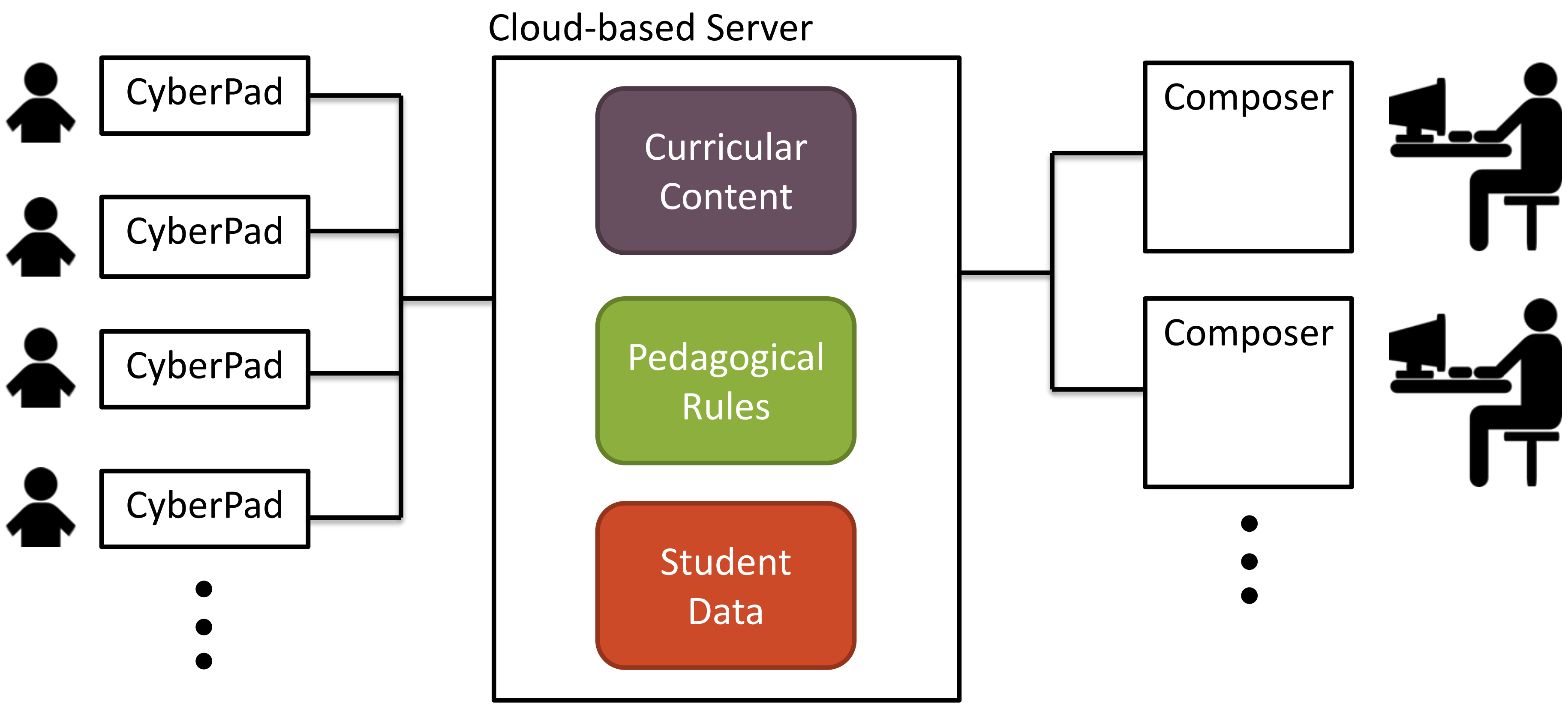
Google Docs

PowerPoint

LEONARDO Architecture Prior to Composer



LEONARDO Architecture with Composer

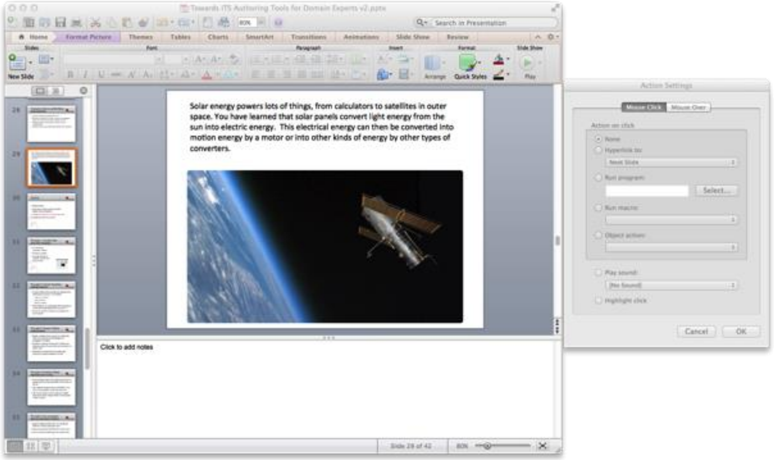


Composer Features

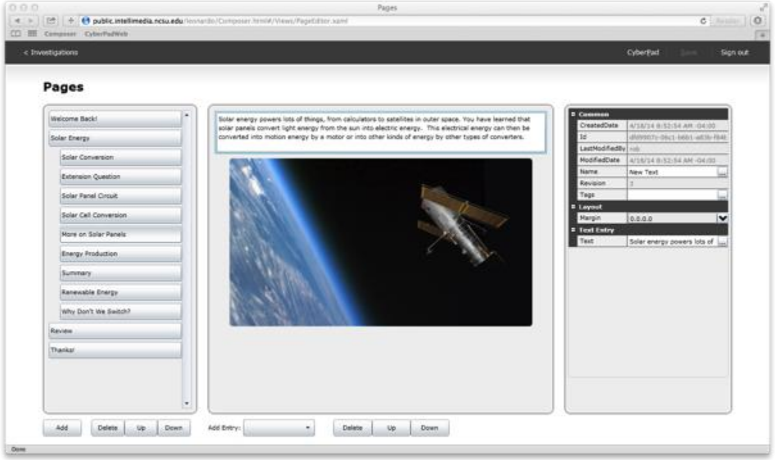
- Simplified workflow
- Familiar UI
- Rapid iteration
- Curricular content stored in cloud
- Web-based authoring tool

Principle 1: Familiar User Interface Paradigm

- UI is the most important feature
- Familiar to author
- Leverage decades of usability and efficiency improvements



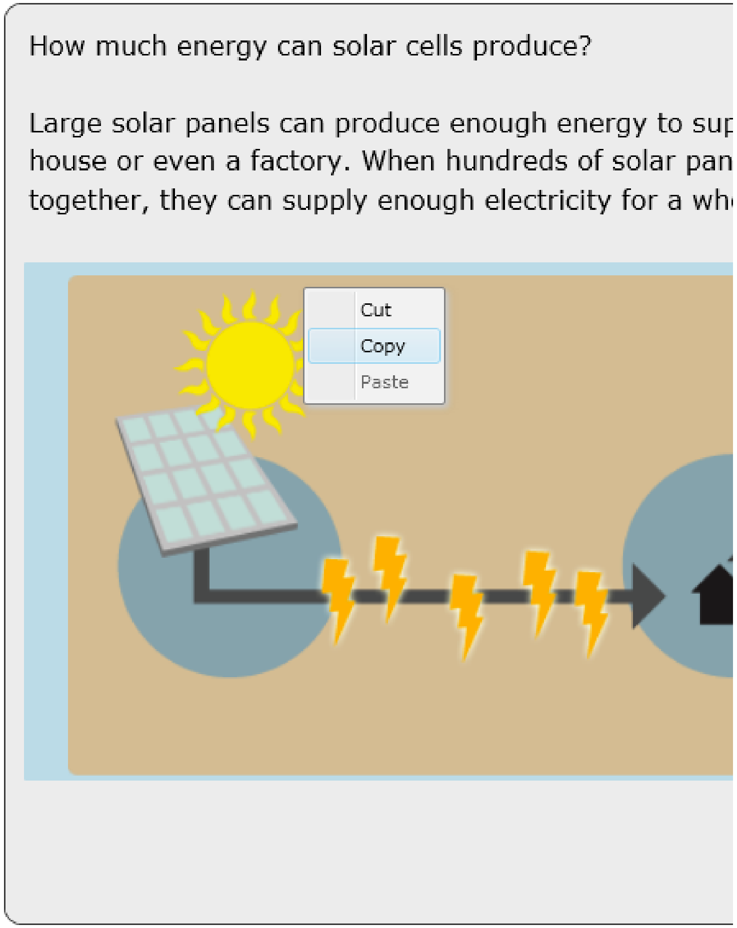
PowerPoint



Composer

Principle 2: Standard Editing Features

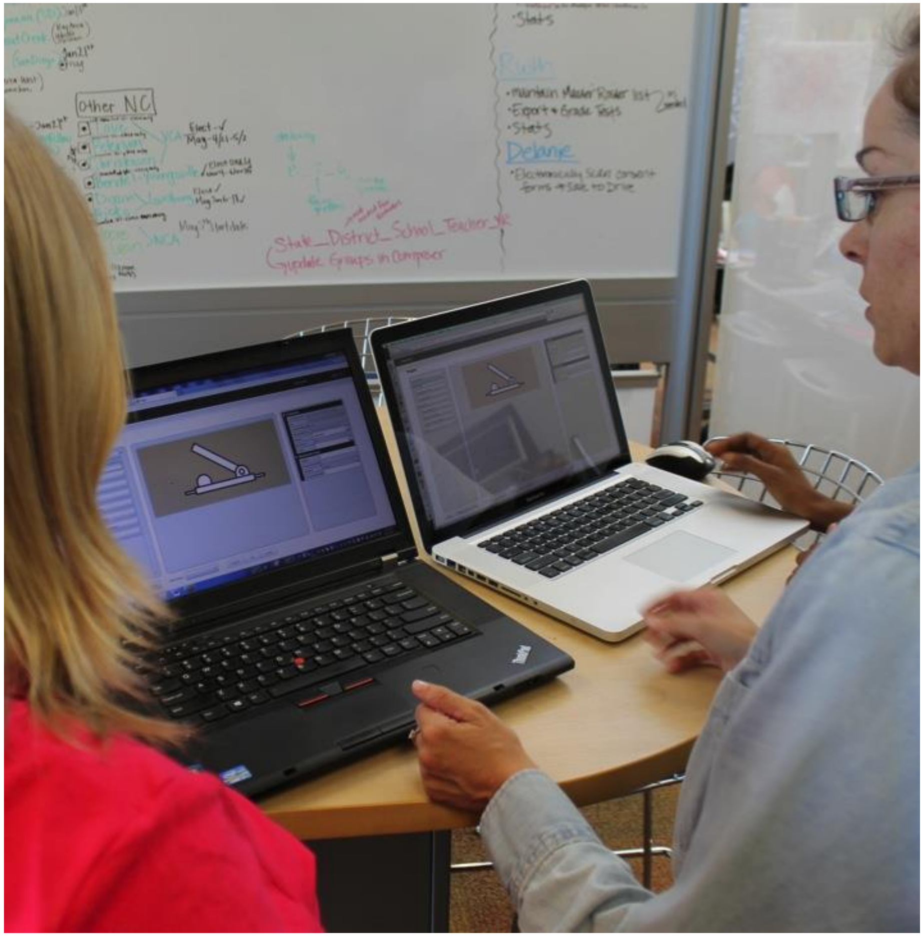
- Relied upon by authors
  - Copy, Cut, and Paste
  - Undo and Redo
  - Revision Tracking
- Can profoundly affect curricular content storage
- Should not be left as a feature to be added at the end of project



Principle 3: Author Collaboration

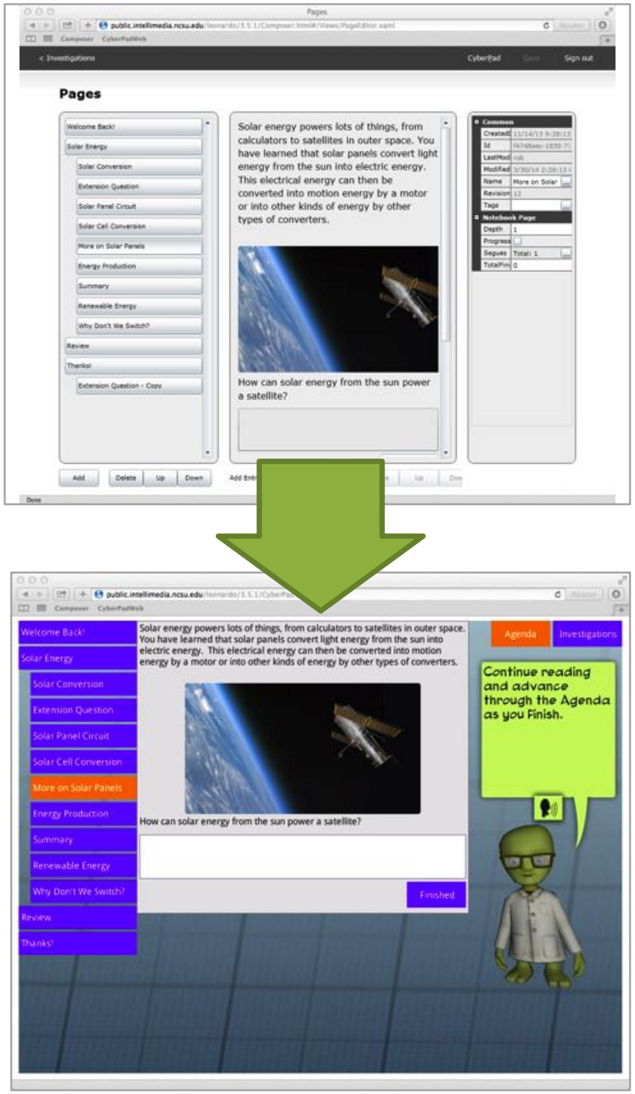
the intelliMEDIA group

- Multiple author collaboration
- Facilitates communities of authors
- Increase both quality and quantity of content



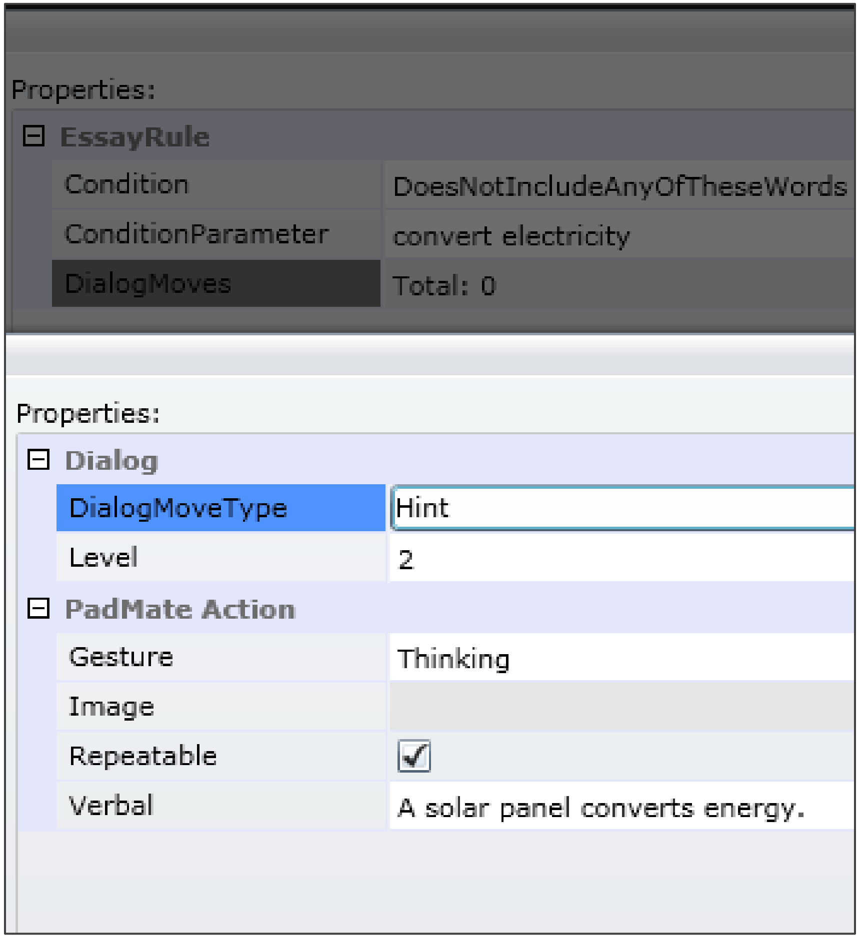
Principle 4: Rapid Iteration

- WYSIWYG or live connection to the ITS
- Changes can be quickly seen in the context of the ITS
- Test ITS behavior while editing rules



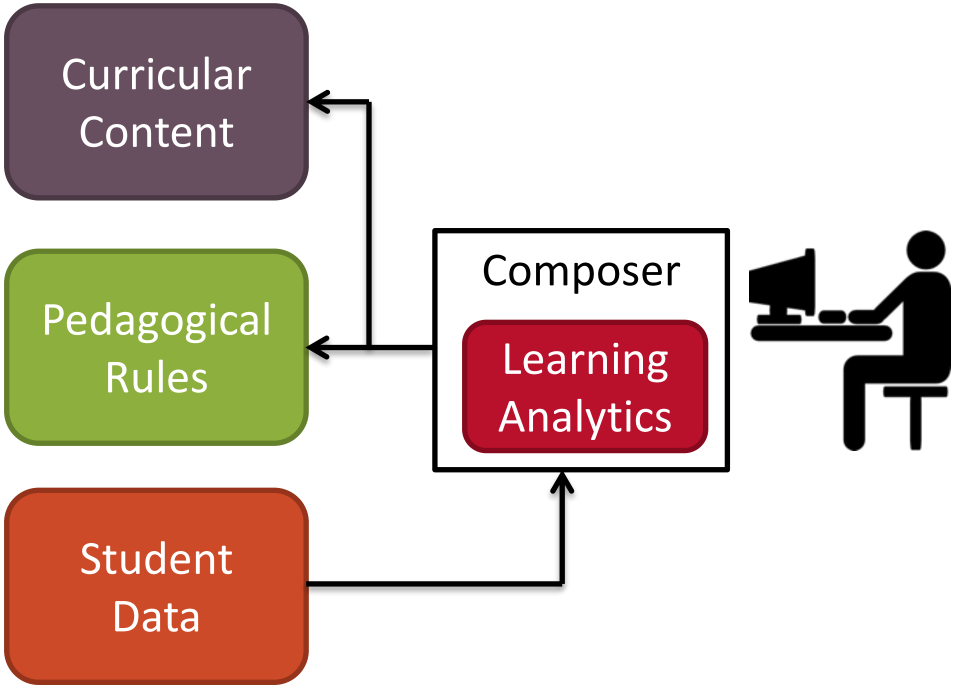
Principle 5: Accommodate Novice and Expert Authors

- 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.