



Creating and Experimenting with Models

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STEM Smart

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The Concord
Consortium

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.





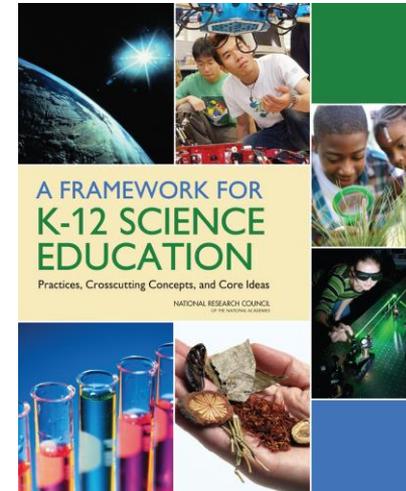
What will we do today?

- 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

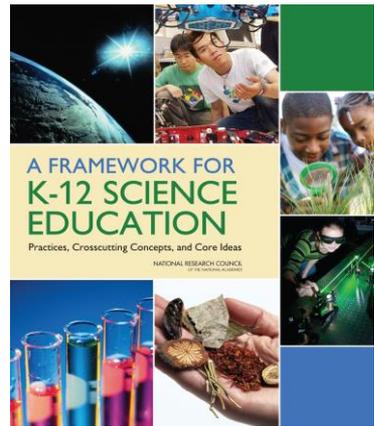
Goals of the project

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)



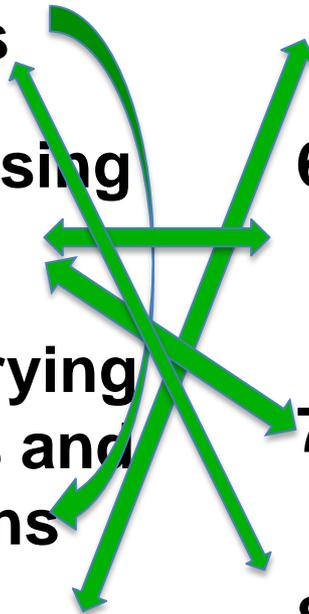
What is really different about the Framework and NGSS?



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

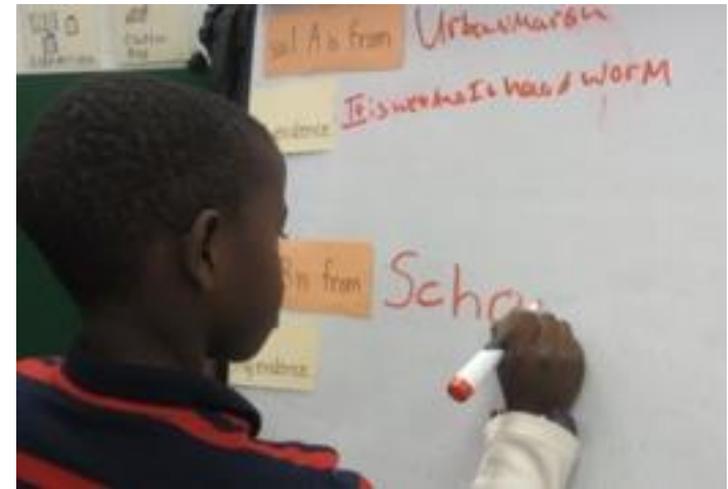
The multiple ways of knowing and doing that scientists and engineers use to study the natural world and design world.

- 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 phenomena



- 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

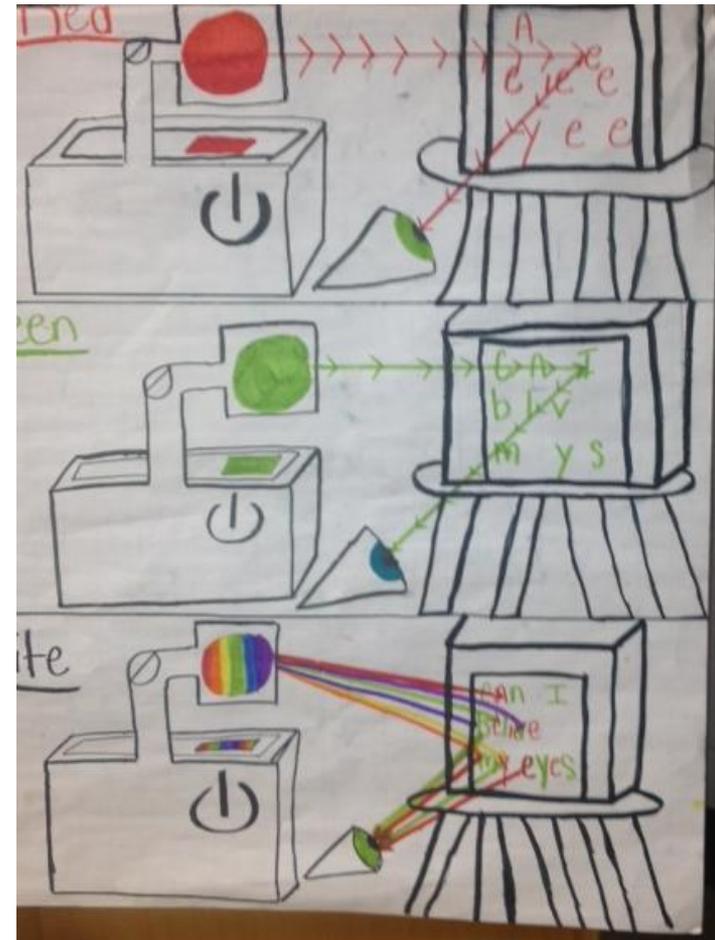


| Grades K - 2 | Grades 3 - 5 | Middle School | High School |
|---|---|---|---|
| Develop a simple model that represents a proposed object or tool. | Develop and revise models collaboratively to measure and explain frequent and regular events. | Develop models to describe unobservable mechanisms. | Develop, 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 exist 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

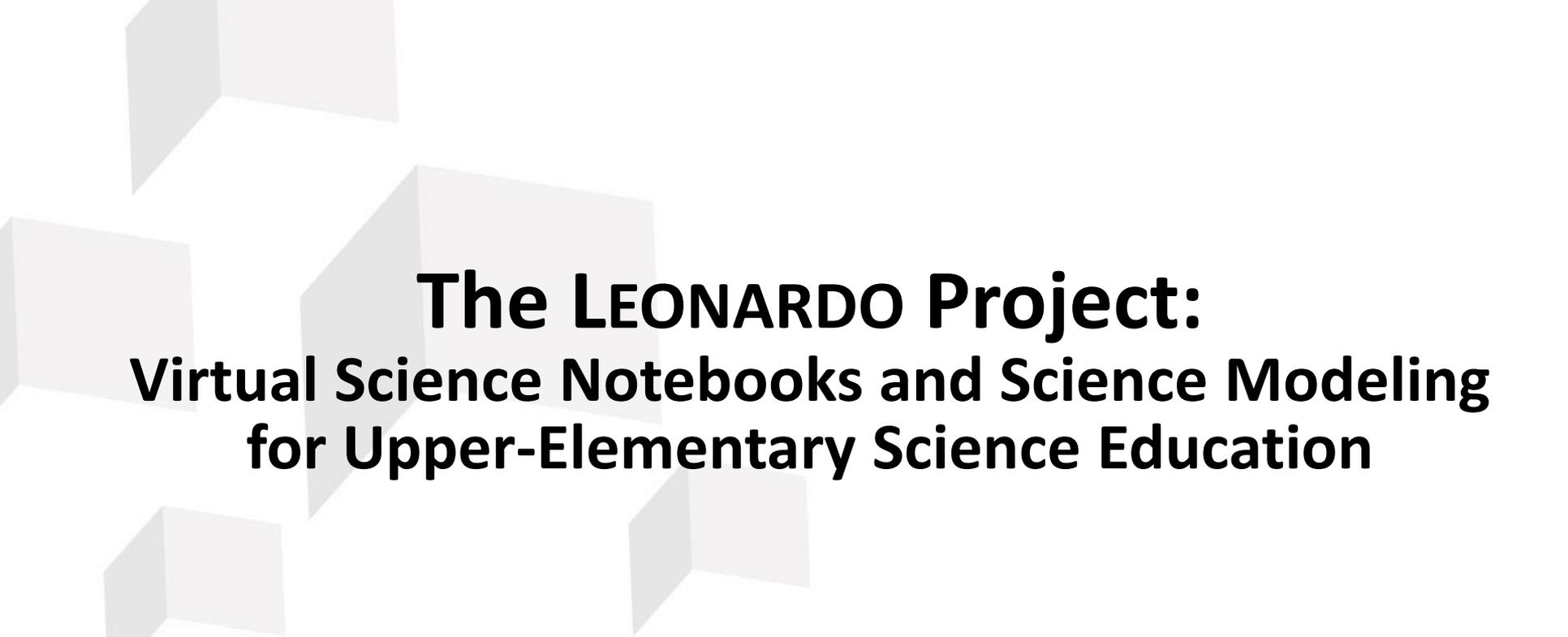
Joe: krajcik@msu.edu twitter: @krajcikjoe

Partners



Funder





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

James C. Lester Robert G. Taylor

North Carolina State University



the IntelliMEDIA
group

Center for Educational Informatics



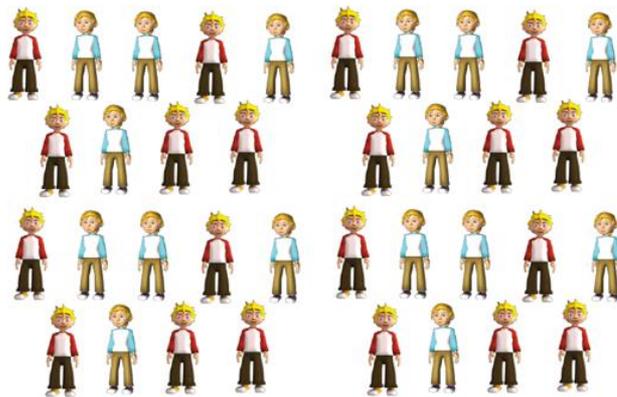
Transforming education with next-generation learning technologies



- NAE Grand Challenge for Engineering:
Advanced Personalized Learning
- Mission: Design, deploy, and investigate adaptive learning environments



One-on-One Tutoring

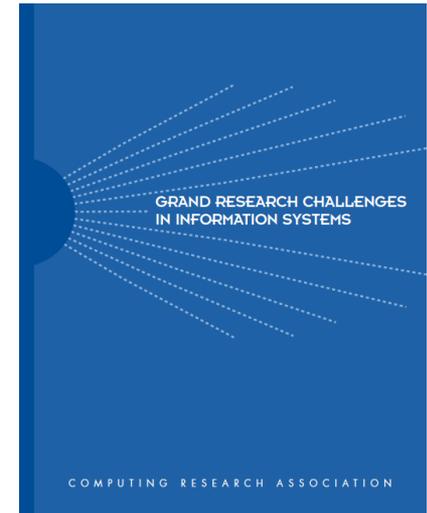


Design Challenge



“Provide a teacher for every learner”

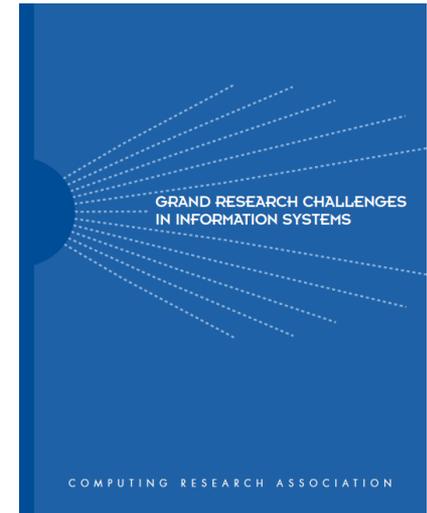
- Learn at their own pace and in their own style
- Receive continuous, customized and meaningful feedback and assessment
- Acquire new skills in a way that is compelling and engaging



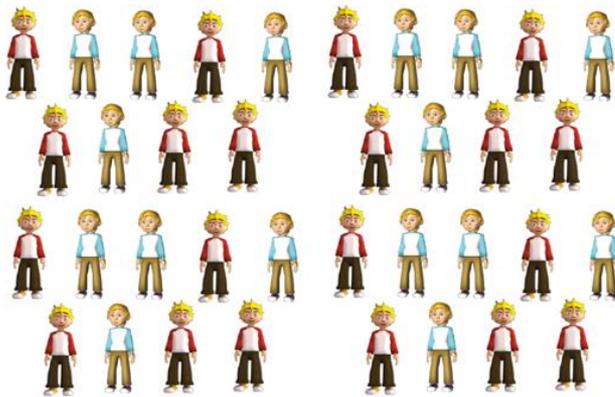
Design Challenge



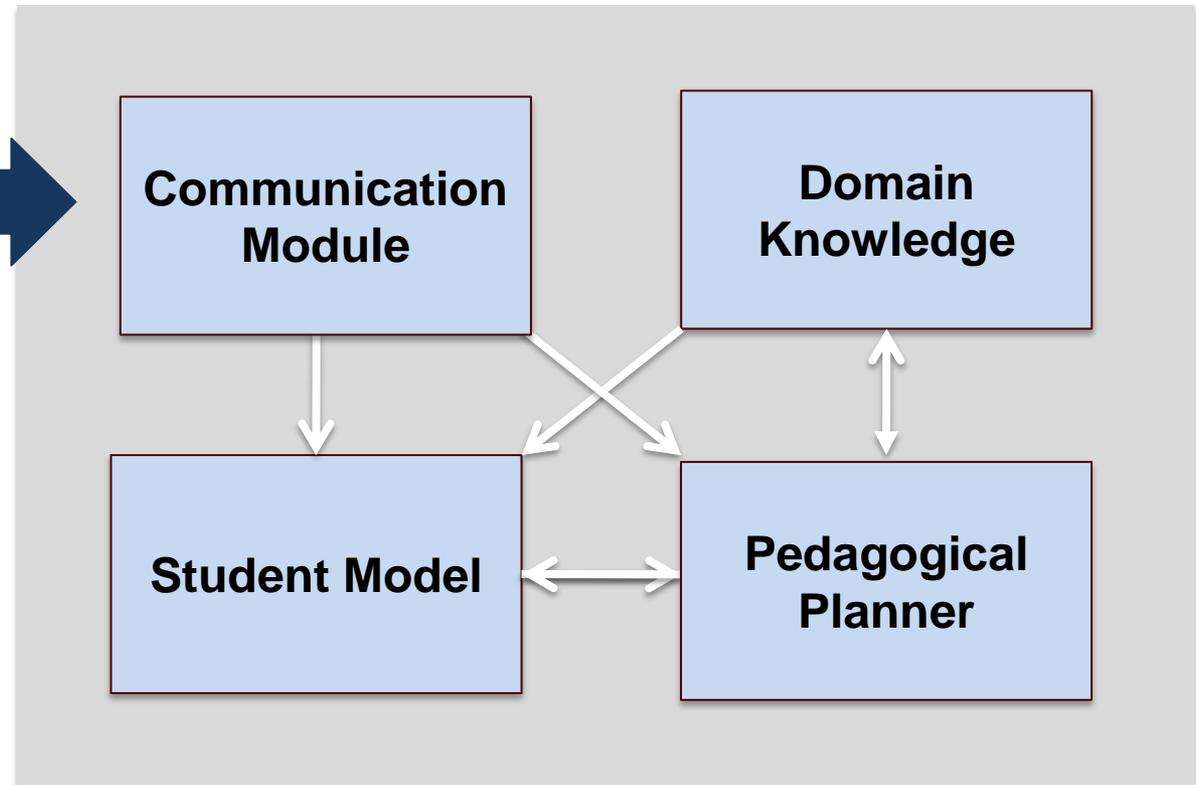
“... provide learning environments that approach the effectiveness of one teacher for every learner. Such systems, properly used, can produce a significantly better-educated populace by combining advances in learning sciences with advances in information technology.”



Personalized Learning Technologies



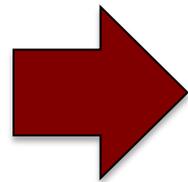
Intelligent Tutoring Systems



What's Right with This Picture?



- Student modeling
- Pedagogical planning
- Adaptive feedback

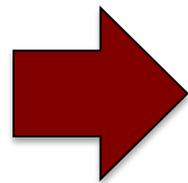


Cognitive effectiveness

What's Wrong with This Picture?



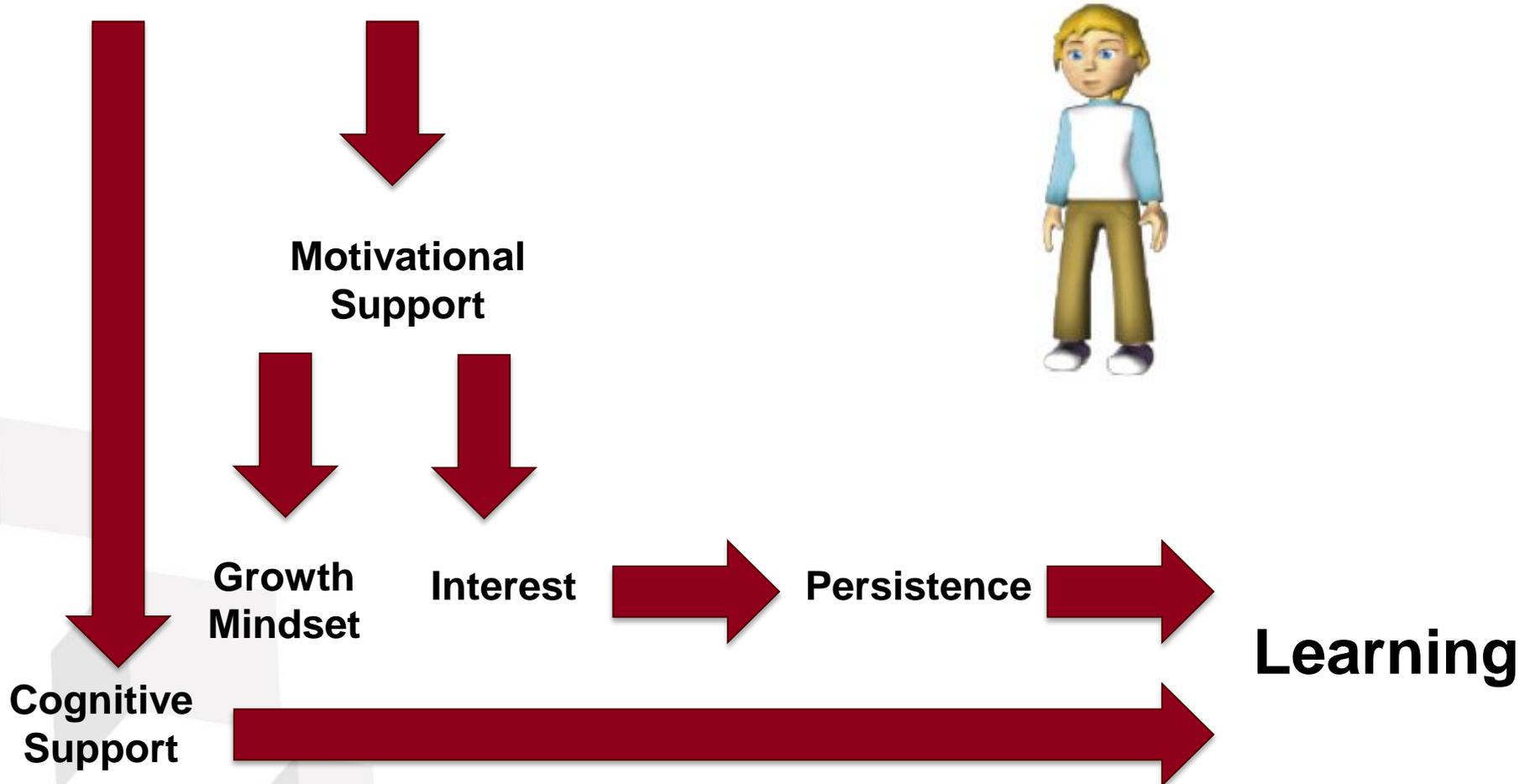
- Does not feature science modeling
- Inquiry not playing a central role
- Missing key benefits of science notebooks
- Engagement not key design objective



Rich inquiry + lab-based
science + engagement

Personalized Learning Hypothesis

Interactive Modeling + Pedagogical Agents



The LEONARDO Project



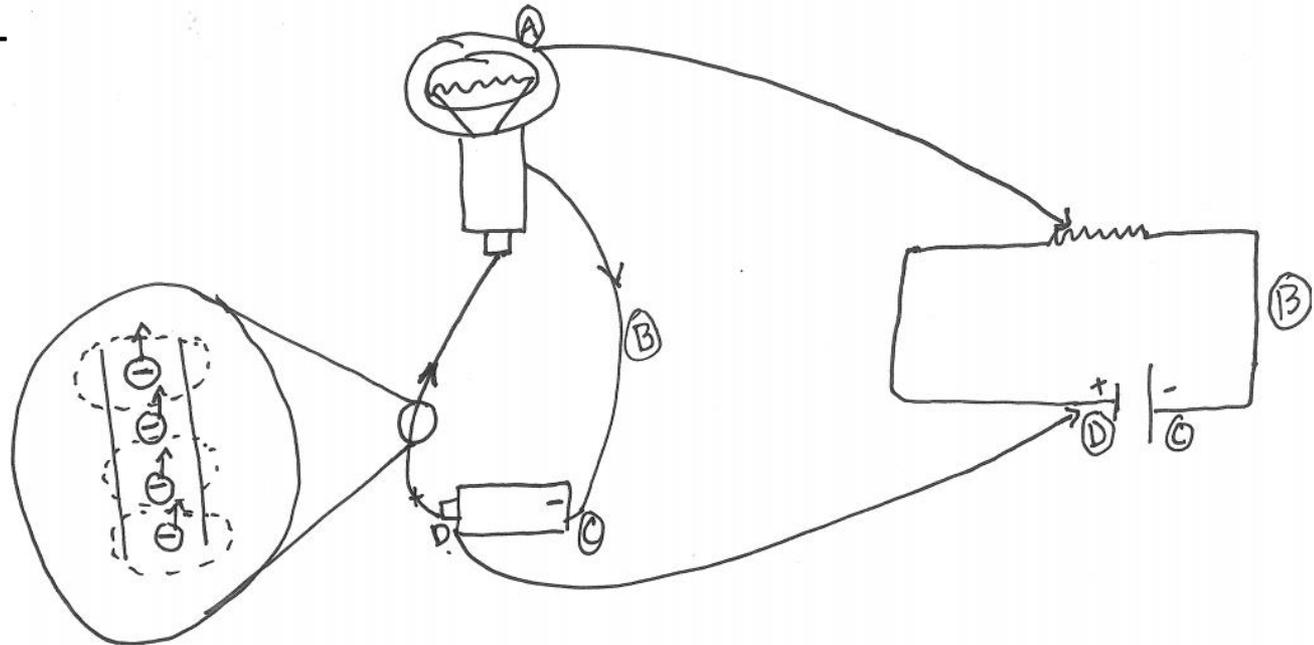
- Intelligent science notebook
- Guided inquiry-based learning
- Upper elementary science education
- Diagrammatic interactive modeling
- Multi-platform delivery
 - Tablet
 - Web browser

Diagramming in Science Education

Drawing is central to thinking and learning about science

[Ainsworth et al., 2010]:

- Improve sense-making
- Communicate knowledge
- Reveal understanding

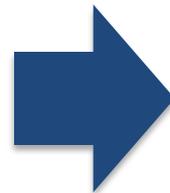
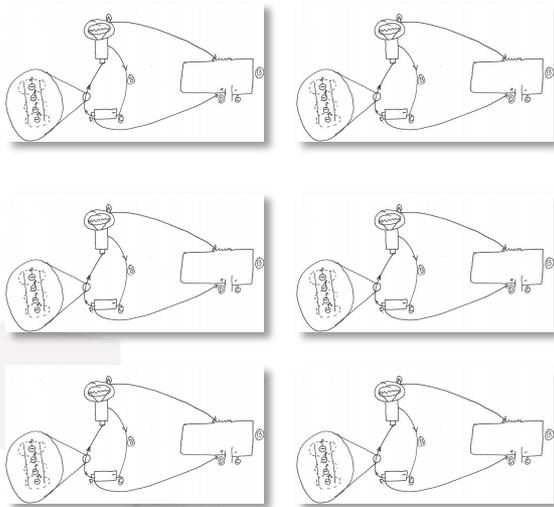


Drawing in Science Education



Mining Learner-Generated Science Drawings

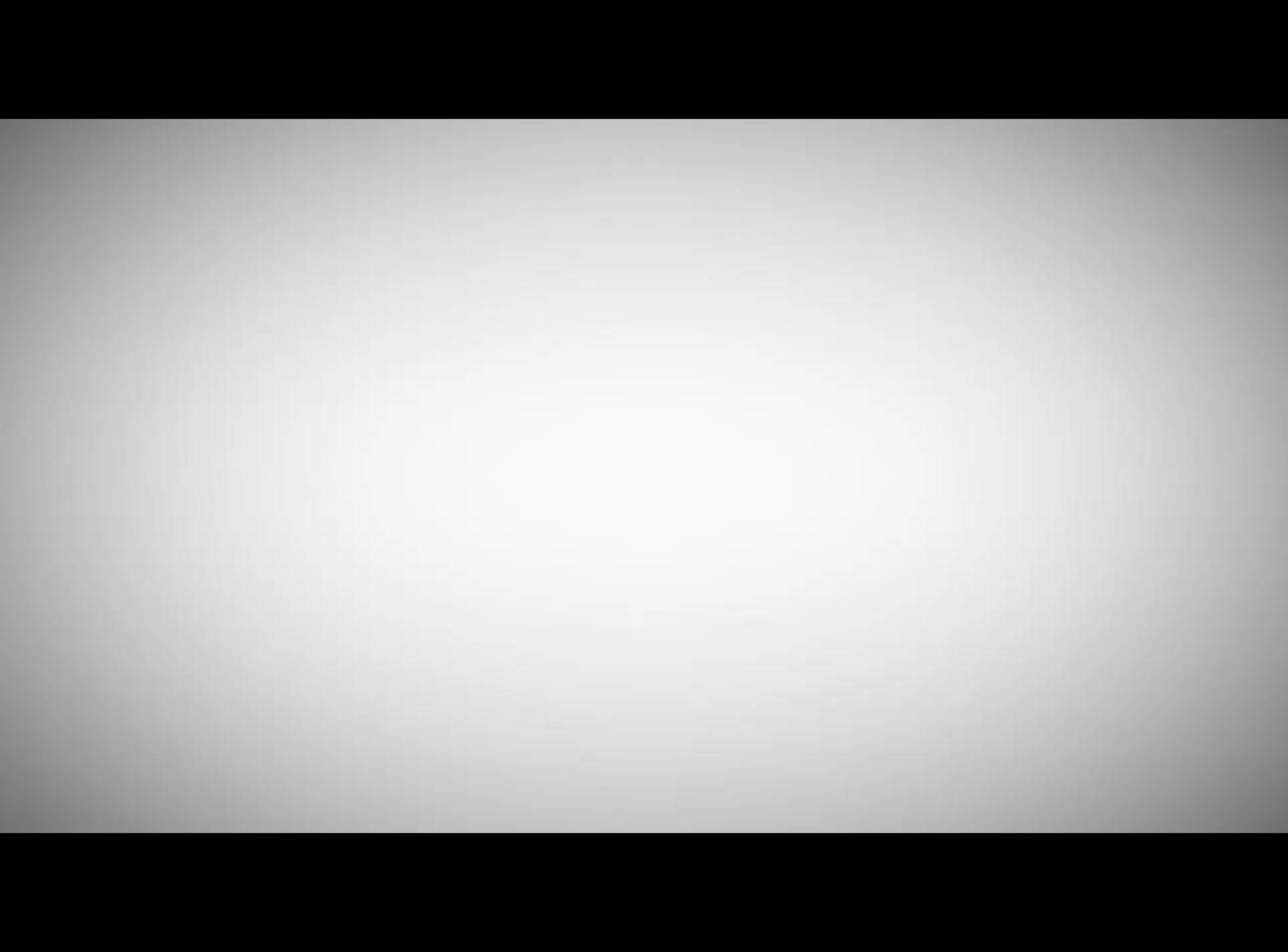
Student Drawings



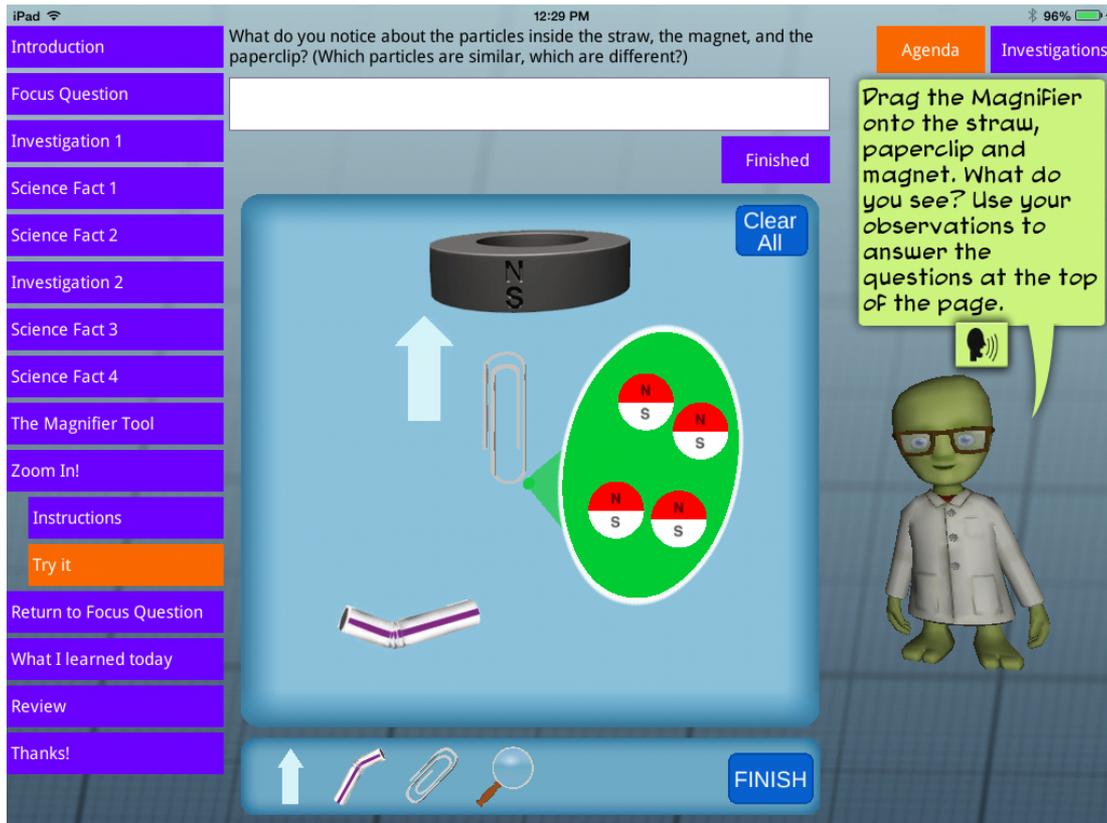
Diagrammatic
Student
Model



- Personalized Scaffolding
- Formative Assessments
- Misconception Identification
- Knowledge Modeling



The LEONARDO Project



iPad 12:29 PM 96%

Introduction
Focus Question
Investigation 1
Science Fact 1
Science Fact 2
Investigation 2
Science Fact 3
Science Fact 4
The Magnifier Tool
Zoom In!
Instructions
Try it
Return to Focus Question
What I learned today
Review
Thanks!

What do you notice about the particles inside the straw, the magnet, and the paperclip? (Which particles are similar, which are different?)

Agenda Investigations

Finished

Clear All

Drag the Magnifier onto the straw, paperclip and magnet. What do you see? Use your observations to answer the questions at the top of the page.

FINISH

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

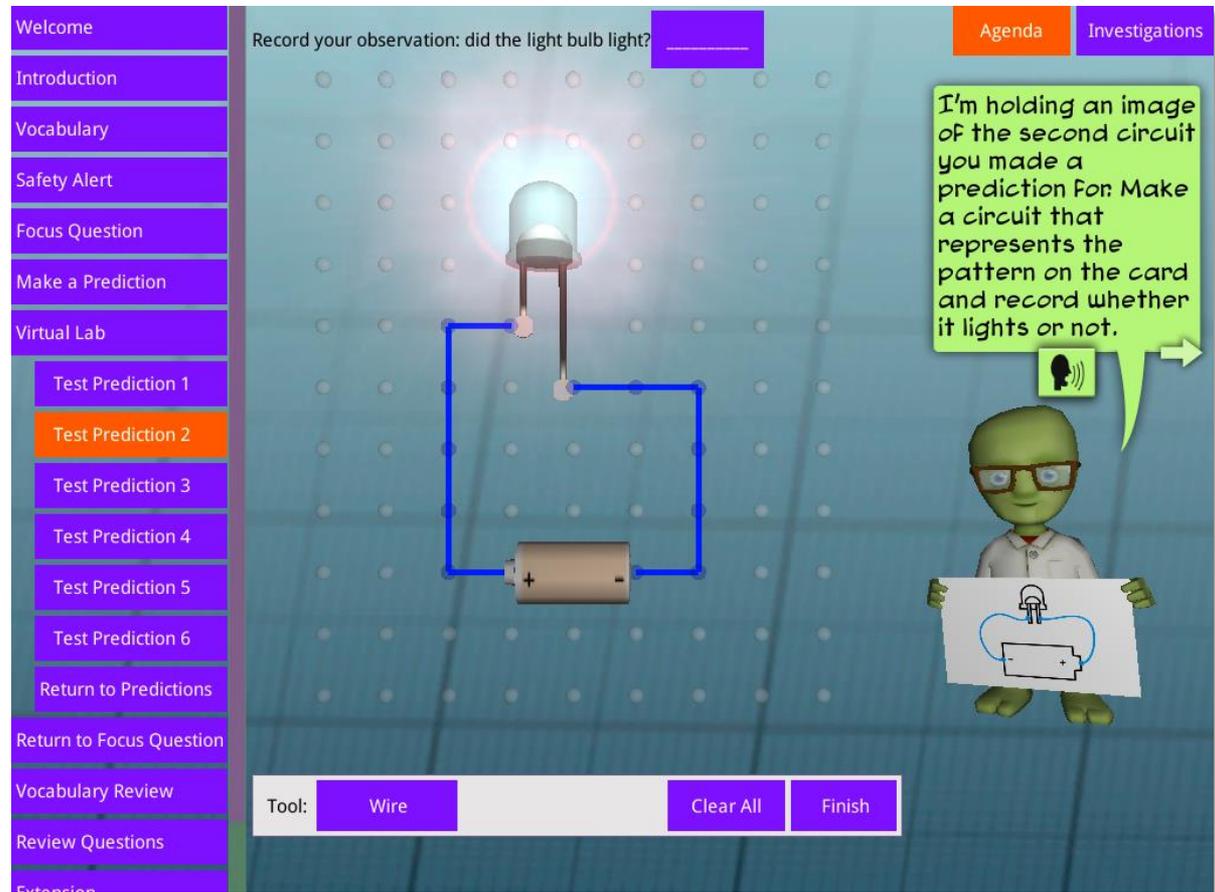
LEONARDO CyberPad



The screenshot shows the Leonardo CyberPad interface on an iPad. The top status bar displays 'iPad', signal strength, '6:07 PM', and '100%' battery. A left sidebar contains a menu of topics: Welcome, Introduction, Write what you know (highlighted in orange), A Flashlight, Flashlight Parts, Circuits, Vocabulary, Safety Alert, Focus Question, Make a Prediction, Virtual Lab, Return to Focus Question, Vocabulary Review, Review Questions, and Thanks!. The main content area shows a series of questions and answers related to energy, with 'Finished' buttons. The questions are: 'What do you think the word energy means?' (answer: 'The word energy means the ability to do work make things move or happen it comes in different forms such as hest light motion chemical and electrical'), 'What can energy be used for?' (answer: 'Energy can be used for tv phones computuers and tabalats phone wires the building that runs off of'), and 'Where does energy come from?' (answer: 'Energy comes from a d-cell souces'). A right sidebar has 'Agenda' and 'Investigations' tabs. A green speech bubble contains the text: 'Think back to your experiences and give me more information in your scientific explanation.' Below the speech bubble is a small icon of a head with sound waves and a 3D cartoon character of a scientist wearing a white lab coat and glasses.

Modeling via Drawing

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



The screenshot shows a virtual lab interface. On the left is a navigation menu with items: Welcome, Introduction, Vocabulary, Safety Alert, Focus Question, Make a Prediction, Virtual Lab, Test Prediction 1, Test Prediction 2 (highlighted in orange), Test Prediction 3, Test Prediction 4, Test Prediction 5, Test Prediction 6, Return to Predictions, Return to Focus Question, Vocabulary Review, Review Questions, and Extension. The main workspace has a grid background and contains a glowing light bulb connected to a battery by blue wires. At the top, it asks "Record your observation: did the light bulb light?" with a blank line. On the right, there are tabs for "Agenda" and "Investigations". A green speech bubble contains the text: "I'm holding an image of the second circuit you made a prediction For: Make a circuit that represents the pattern on the card and record whether it lights or not." Below the speech bubble is a lightbulb icon and a green cartoon scientist holding a card with a circuit diagram. At the bottom, a "Tool:" menu shows "Wire" selected, along with "Clear All" and "Finish" buttons.

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



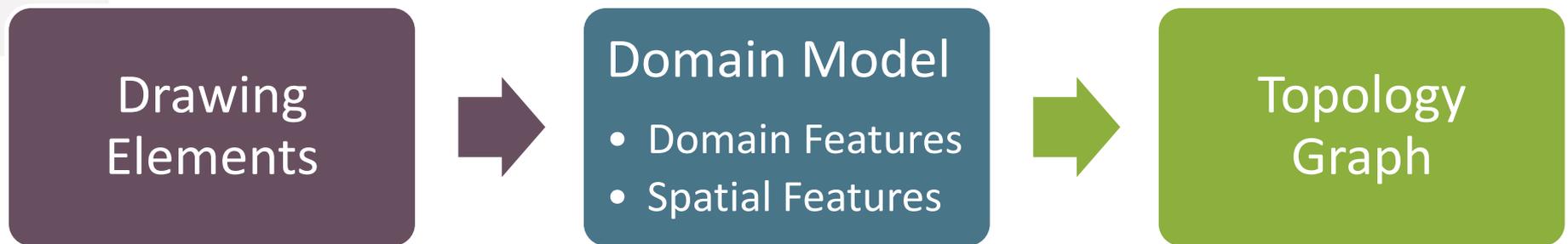
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 - “Execution” variance

Topological Representation

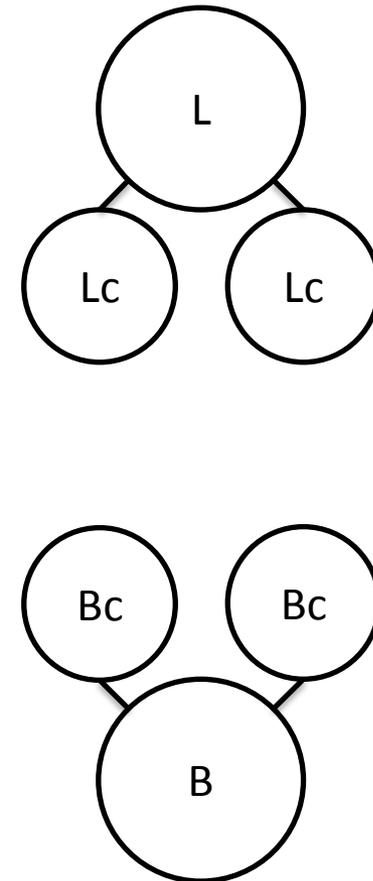


Labeled Graph Encoding

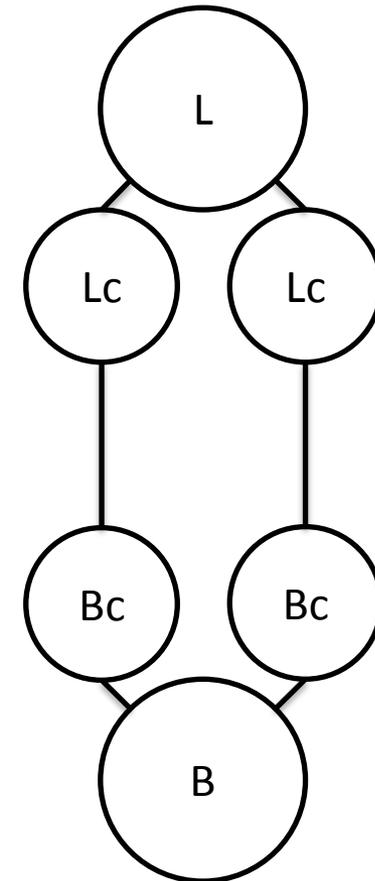
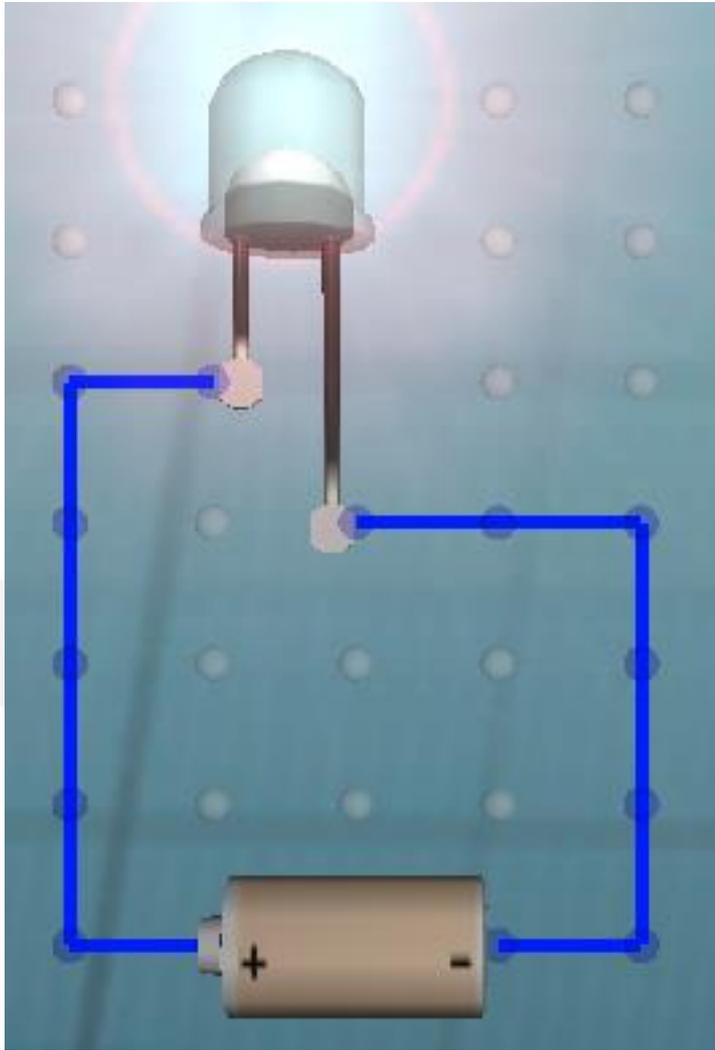
- Nodes represent key graphical elements
- Edges represent topographical relations
- Capable of representing broad array of relations between objects



Topology: Elements



Topology: Connectivity



Middle School Microbiology & Literacy - Free!



A screenshot of the website for "Crystal Island Lost Investigation". The page has a light green and white color scheme. At the top left is the title "CRYSTAL ISLAND Lost Investigation" with "CRYSTAL ISLAND" in green block letters and "Lost Investigation" in a brown script font. To the right is the CEI logo (Center for Educational Informatics). Below the title is a navigation menu with buttons for "ABOUT", "GETTING STARTED", "CURRICULAR CONTENT", "RESEARCH & TECHNOLOGY", "PUBLICATIONS", "COMMUNITY", and "SUPPORT". The main content area features a large image of a wooden building on a tropical island with palm trees, captioned "WELCOME TO CRYSTAL ISLAND: LOST INVESTIGATION". Below this are three smaller featured sections: 1) "BACTERIA STRUCTURE" with a microscopic image of a cell and a "Read more" link. 2) A classroom scene with students at computers, with a "Read more" link. 3) A computer screen showing a game interface, with a "Read more" link.

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

cei-contact@ncsu.edu

Download Information - Free!



- ABOUT
- GETTING STARTED
- CURRICULAR CONTENT
- RESEARCH
- TEAM
- COMMUNITY
- TEACHERS SITE



EXPERIMENT WITH INTERACTIVE MODELS OF PHYSICAL PHENOMENA

NC STATE UNIVERSITY

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

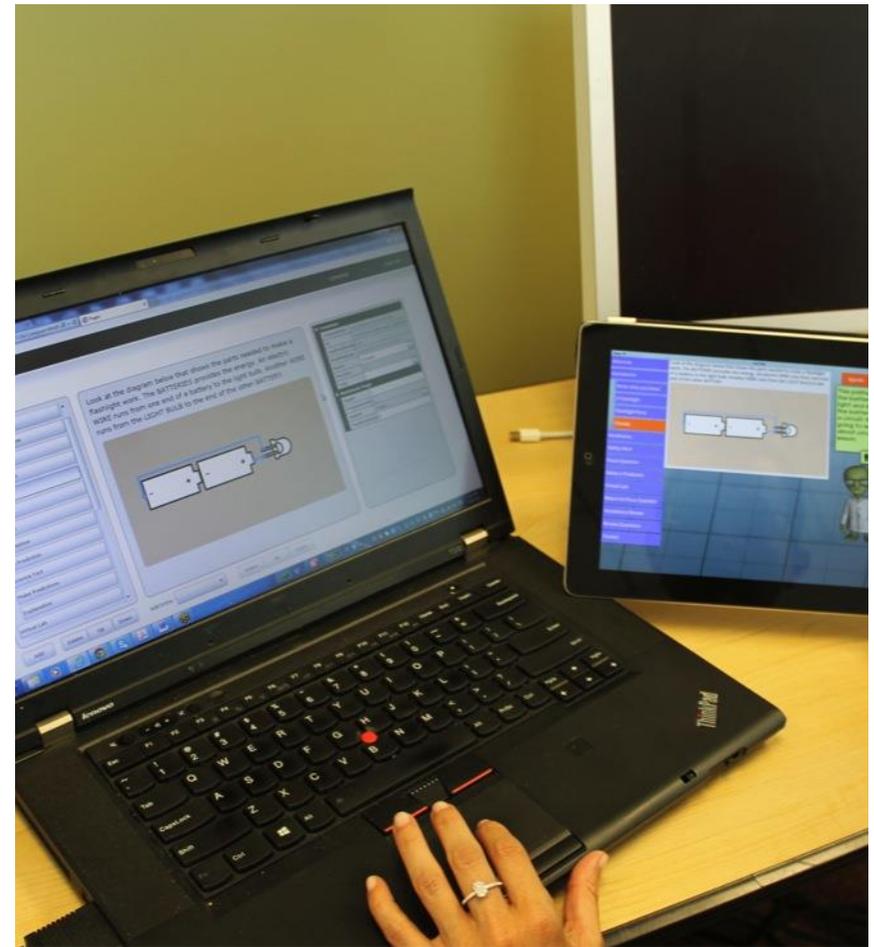
cei-contact@ncsu.edu

LEONARDO CyberPad Laptop Demonstration



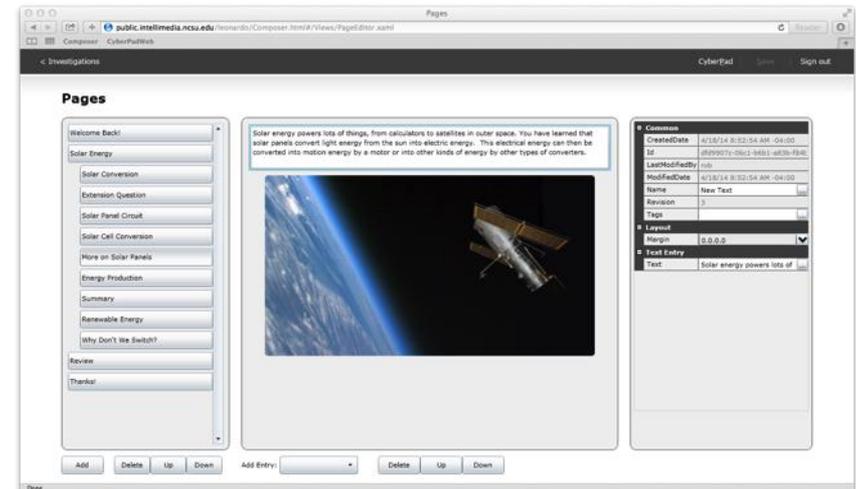
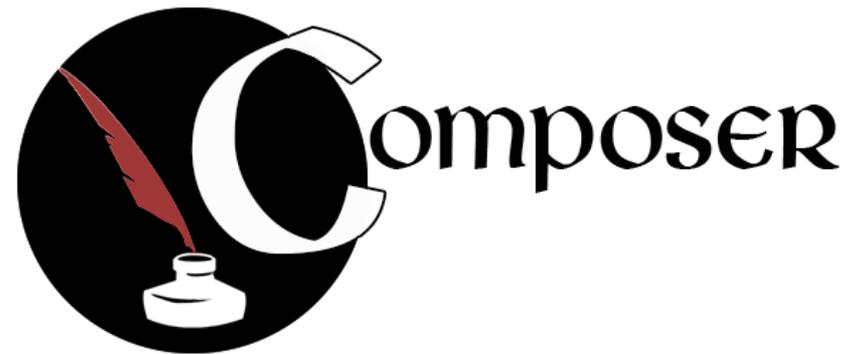
Challenges of Adaptive Learning Environment Authoring

- 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



LEONARDO Authoring

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



Pages
Reader
+

public.intellimedia.ncsu.edu/leonardo/3.5.1/Composer.html#/Views/PageEditor.xaml
Composer CyberPadWeb

< Investigations
CyberPad Save Sign out

Pages

Welcome

Introduction

Write what you know

A Flashlight

Flashlight Parts

Circuits

Vocabulary

Safety Alert

Focus Question

Make a Prediction

Science Fact

Make Predictions

Explanation

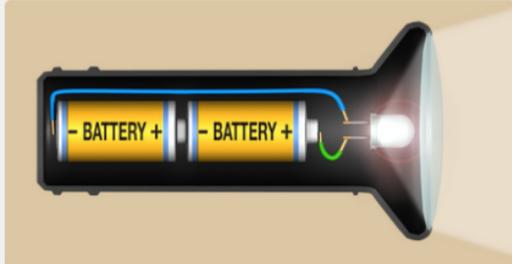
Virtual Lab

Test Prediction 1

Test Prediction 2

Test Prediction 3

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.

Common

| | |
|----------------|--------------------------------|
| CreatedDate | 11/14/13 9:27:04 PM -05:00 |
| Id | 806878a8-6531-fb60-5ad0-bc6eb1 |
| LastModifiedBy | rob |
| ModifiedDate | 11/14/13 9:27:04 PM -05:00 |
| Name | New MultipleChoice |
| Revision | 7 |
| Tags | |

Input Entry

EnableFinishedBy

ReadOnly

Layout

Margin 0.0.0.0

Multiple Choice Entry

Choices Total: 3

QuestionText A `<select/>` provides the energy

User Data

| | |
|-----------------|--------------------------|
| InternalDataKey | MultipleChoiceEntry-677d |
| UserDataKey | Provides Energy |

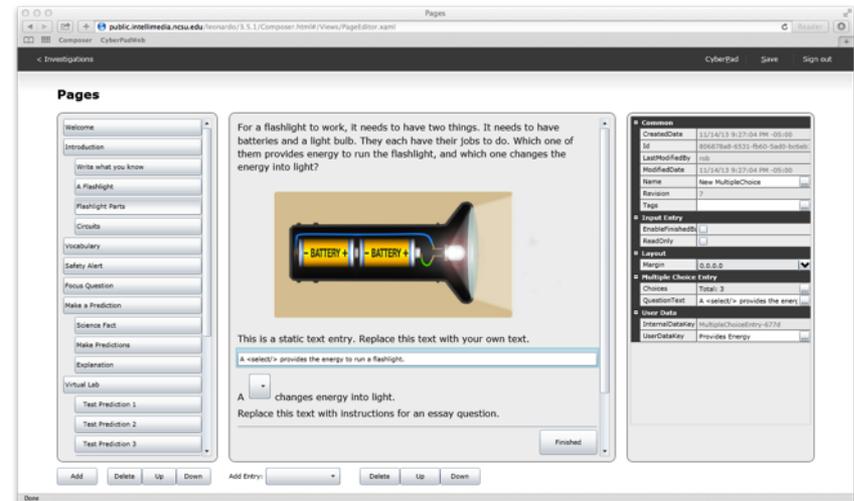
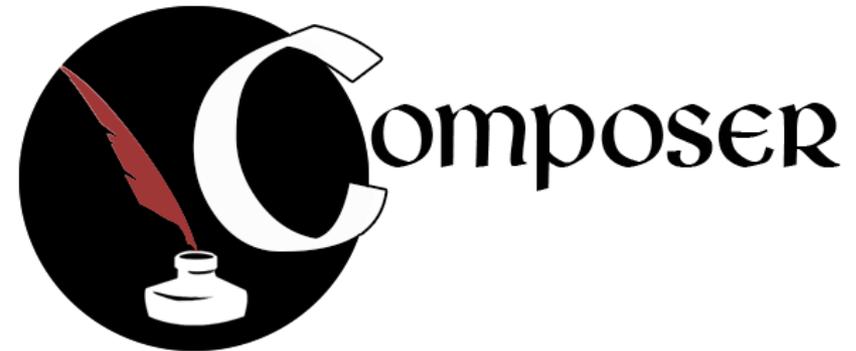
Add Entry:

Done

LEONARDO Composer

Authors use Composer to create:

- Curricular content
- Agent dialogue
- Agent behavior



Prior to Composer

Original authoring workflow:

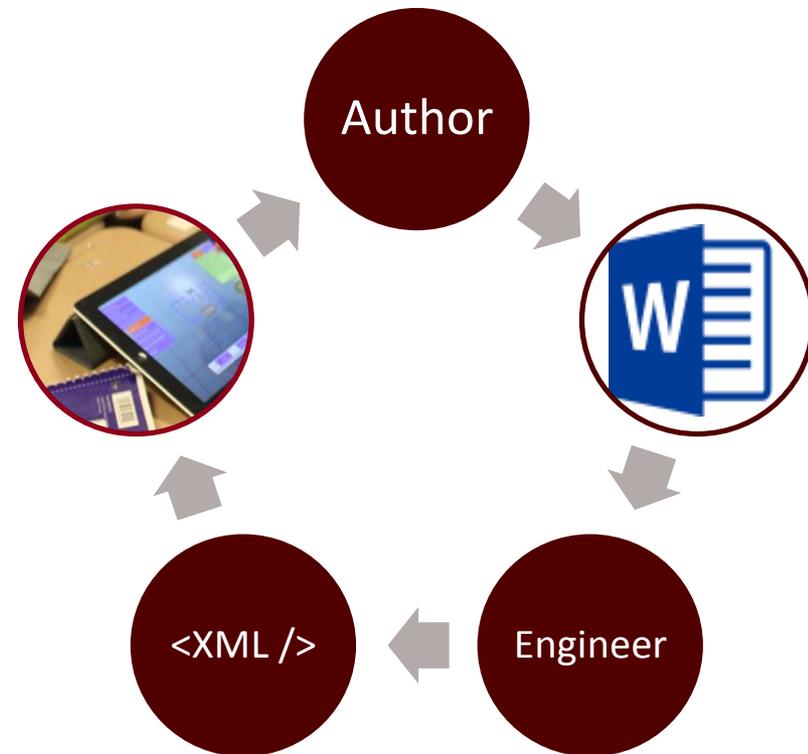
- Word used to author curriculum and agent dialogue
- Doc copied into XML
- XML embedded in the iPad app
- Agent behavior authored in code by software engineers



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



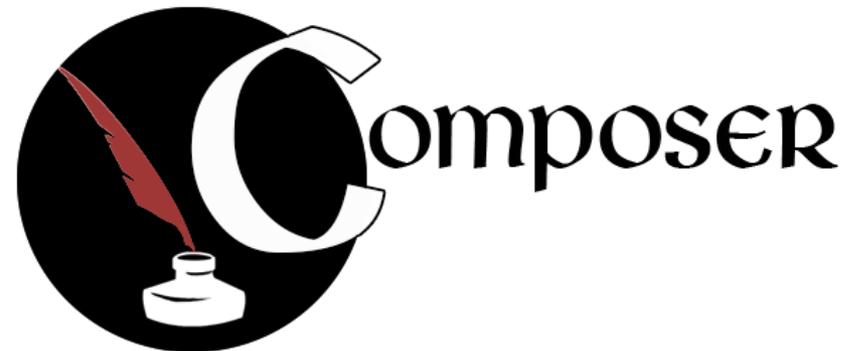
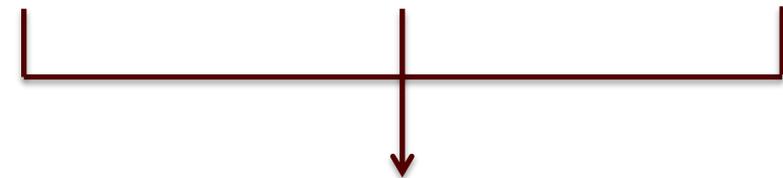
Edmodo



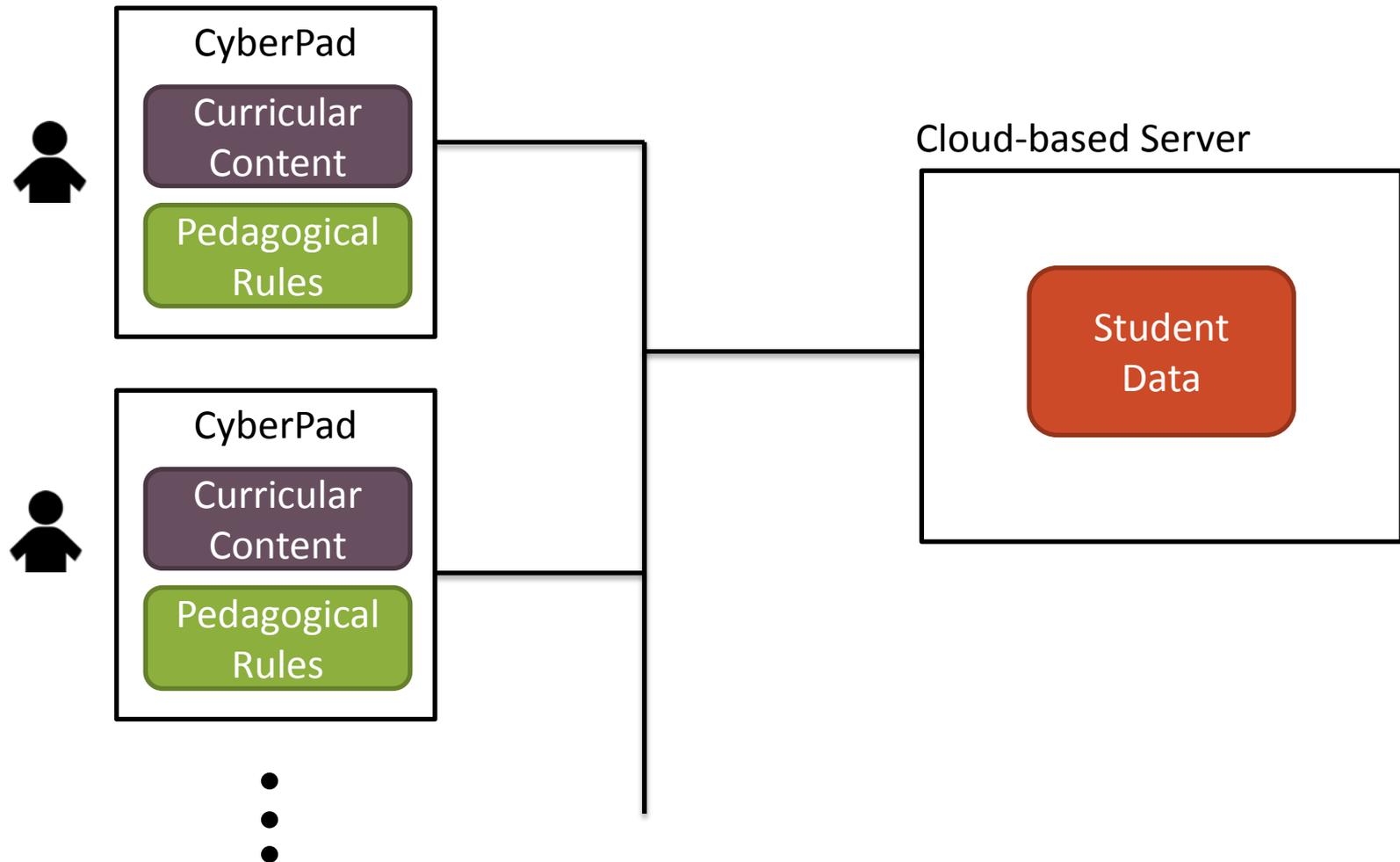
Google Docs



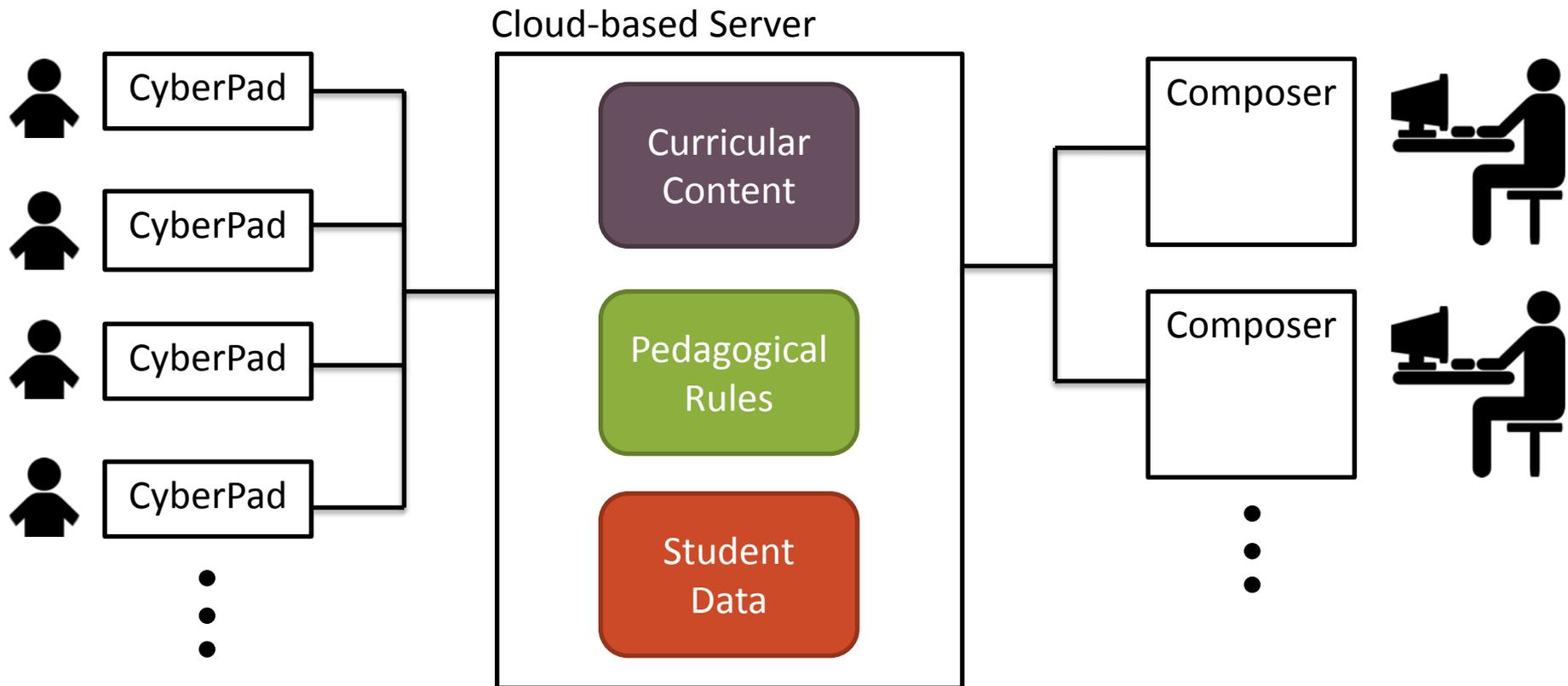
PowerPoint



LEONARDO Architecture Prior to Composer

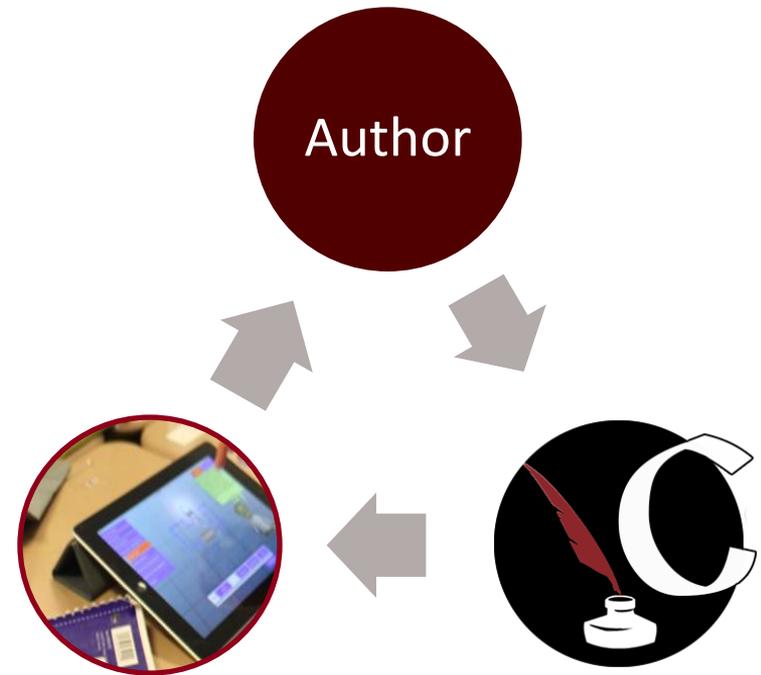


LEONARDO Architecture with Composer



Composer Features

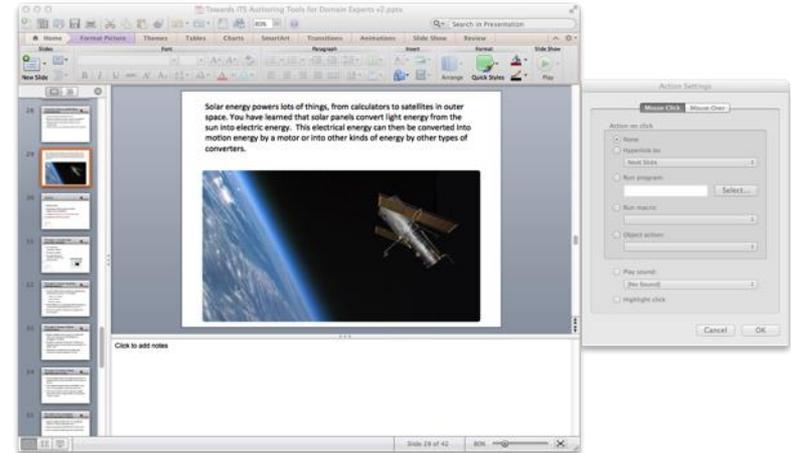
- Simplified workflow
- Familiar UI
- Rapid iteration
- Curricular content stored in cloud
- Web-based authoring tool



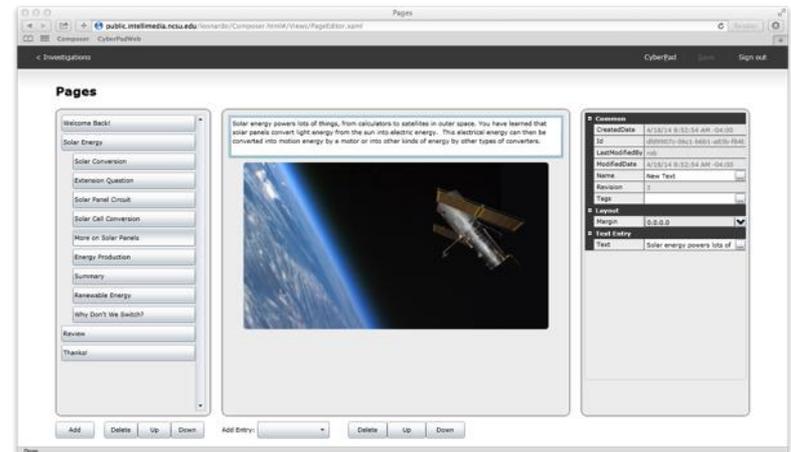
Principle 1: Familiar User Interface Paradigm



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



PowerPoint



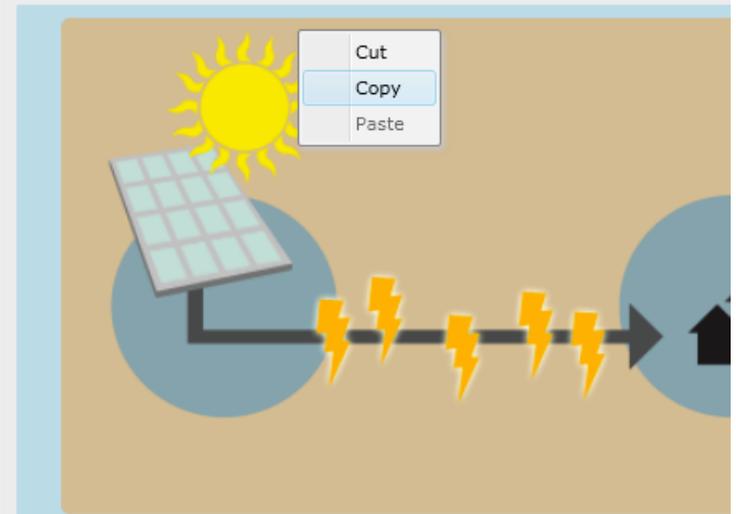
Composer

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

How much energy can solar cells produce?

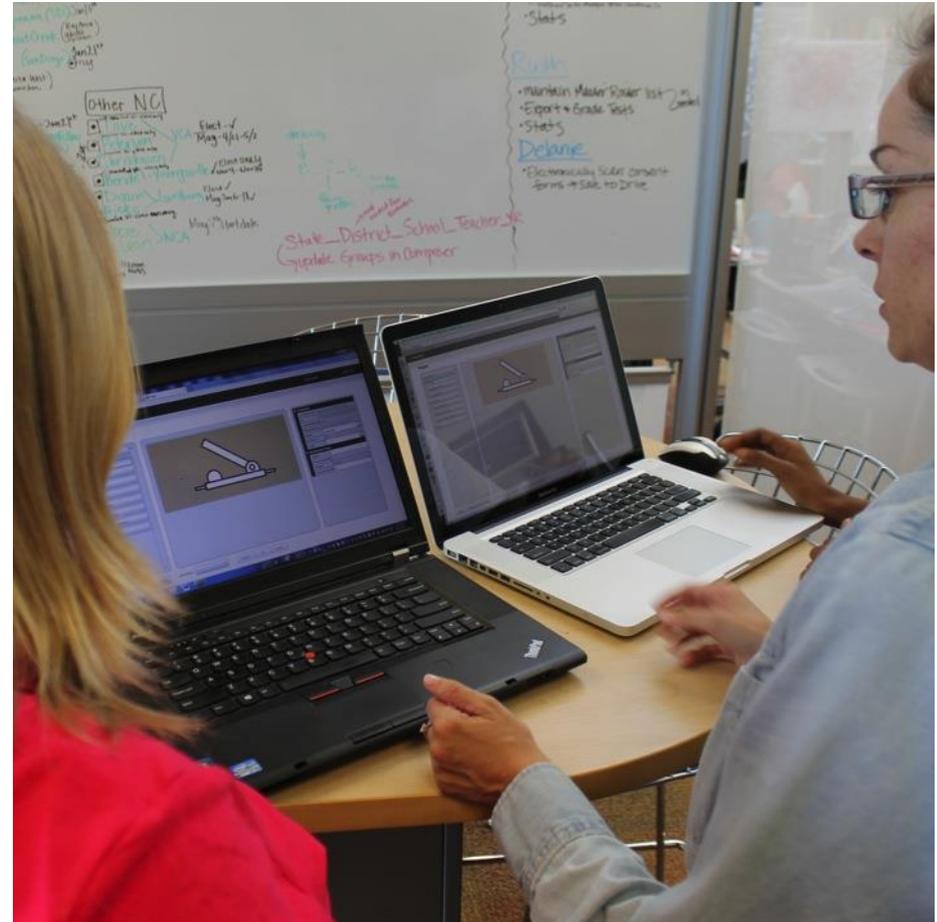
Large solar panels can produce enough energy to supply a house or even a factory. When hundreds of solar panels are put together, they can supply enough electricity for a whole town.



Principle 3: Author Collaboration

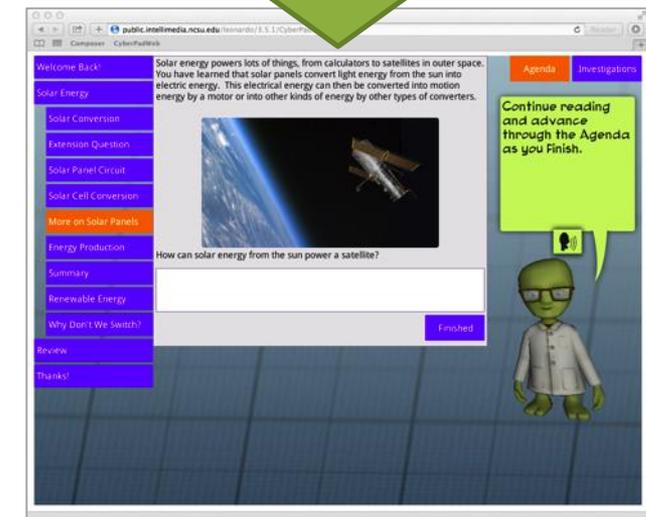


- Multiple author collaboration
- Facilitates communities of authors
- Increase both quality and quantity of content



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

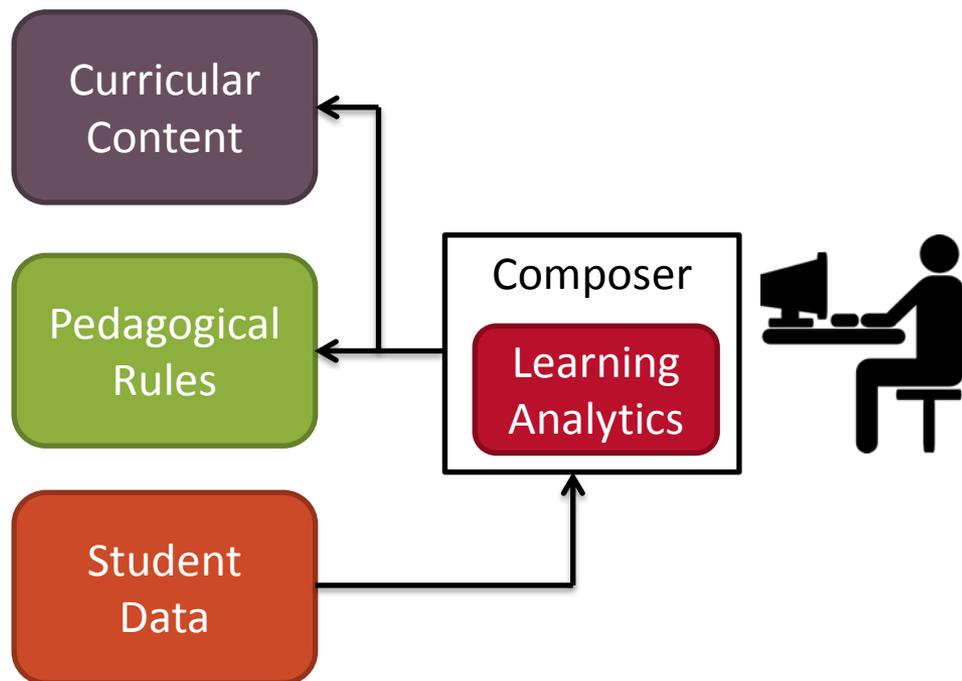
The screenshot displays two sections of a properties panel. The top section is titled 'Properties:' and contains a tree view with 'EssayRule' expanded. It lists three properties: 'Condition' with value 'DoesNotIncludeAnyOfTheseWords', 'ConditionParameter' with value 'convert electricity', and 'DialogMoves' with value 'Total: 0'. The bottom section is also titled 'Properties:' and contains a tree view with 'Dialog' and 'PadMate Action' expanded. The 'Dialog' section has 'DialogMoveType' set to 'Hint' and 'Level' set to '2'. The 'PadMate Action' section has 'Gesture' set to 'Thinking', 'Image' is empty, 'Repeatable' is checked, and 'Verbal' is set to 'A solar panel converts energy.'

| Properties: | |
|--------------------|-------------------------------|
| [-] EssayRule | |
| Condition | DoesNotIncludeAnyOfTheseWords |
| ConditionParameter | convert electricity |
| DialogMoves | Total: 0 |

| Properties: | |
|--------------------|-------------------------------------|
| [-] Dialog | |
| DialogMoveType | Hint |
| Level | 2 |
| [-] PadMate Action | |
| Gesture | Thinking |
| Image | |
| Repeatable | <input checked="" type="checkbox"/> |
| Verbal | A solar panel converts energy. |

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.

