Supports for Elementary Teachers Implementing NGSS: Challenges and Opportunities across Science, Technology, and Engineering

NSF DR K-12 PI Meeting

June 3, 2016

National Science Foundation
WHERE DISCOVERIES BEGIN

The Opportunity

- 3D science learning
- Performance expectations – engaging in science and engineering practices to develop understanding of disciplinary core ideas and cross-cutting concepts
- Capitalize in early learners' interests and abilities to reason scientifically
- Build a foundation for lifelong science learning

The Challenge

- Documented challenges for elementary teachers of science (Banilower et al., 2013):
  - Limited understanding of disciplinary concepts
  - Limited experience w/ reform-based instructional approaches
  - Ineffective curricular resources
  - Limited instructional time for science
- NGSS can further problematize some of these existing challenges

The Need (and Vision)

A comprehensive, systemic network comprised of an array of <u>teacher supports</u> aligned with NGSS-based 3D learning outcomes for students

Teacher Supports

- Many pathways to provide support:
  - Professional development and teacher education
  - Computer-based pedagogical tools
  - Teacher-educative curriculum materials
  - Online communities and mentoring
- Impacting teachers'…
  - Knowledge (PCK, CK, etc.)
  - Beliefs, orientations, self-efficacy
  - Instructional practices

Session Focal Question

How can 3rd-5th-grade teachers be optimally supported to implement innovative, NGSS-based instruction?

Session Goals

1. Share resources, models, and tools (RMTs) designed to support 3rd-5th-grade teachers to implement an array of curricular and instructional interventions reflecting diverse disciplinary concepts and practices embodied in NGSS
2. Explore how these ideas can advance systemic efforts to support high-quality science instruction and student learning

Session Agenda

- Session Introduction (5 minutes)
- Individual Project Overviews (25 minutes)
- Posters (30 minutes)
- Synthesis Discussion (symposia participants and attendees - 25 minutes)
- Wrap-up (5 minutes)

Participants

- Cory Forbes, University of Nebraska-Lincoln, *Modeling Hydrologic Systems in Elementary Science* (MoHSES)
- Deborah Hanuscin, University of Missouri-Columbia, *Quality Elementary Science Teaching* (QuEST)
- May Jadallah, Illinois State University, *Promoting Students' Spatial Thinking in Upper Elementary Grades using Geographic Information Systems*
- Sara Lacy, TERC, *Focus on Energy: Preparing Elementary Teachers to Meet the NGSS Challenge*
- Patricia Paugh, University of Massachusetts Boston, *Multimedia Engineering Notebook Tools to Support Engineering Discourse in Urban Elementary School Classrooms*
- Ji Shen, University of Miami, *Transformative Robotics Experience for Elementary Students* (TREES)
- P. Sean Smith, Horizon Research, Inc., *Knowledge Assets to Support the Science Instruction of Elementary Teachers* (ASSET)

Poster Session Notes

- Session discussion questions:
  - What are unique challenges facing teachers?
  - What RMTs have been developed to support teachers?
  - How might the different RMTs be leveraged together in synergistic ways to enhance these efforts?
- https://goo.gl/k7ktn5

Synthesis Discussion

- What are unique challenges facing teachers?
- What RMTs have been developed to support teachers?
- How might the different RMTs be leveraged together in synergistic ways to enhance these efforts?

Modeling Hydrologic Systems in Elementary Science (MoHSES)

Cory Forbes[1], Tina Vo[1], Laura Zangori[2], & Christina Schwarz[3]

[1]University of Nebraska-Lincoln

[2]University of Missouri-Columbia

[3]Michigan State University

2016 NSF DR K-12 PI Meeting

MOHSES
Modeling Hydrologic Systems in Elementary Science

SCIENCE LITERACY IANR

MoHSES Project

- Exploratory DR K-12 (2012-Present)
- 3rd-grade teachers and students
- Two goals
  - Promote 3rd-grade students' model-based reasoning about water through curriculum materials enhancement and instruction
  - Research to investigate elementary students' model-based reasoning about water
- Design-based research around FOSS Water module

MoHSES Teachers

- 6 3rd-grade teachers
- One 1st-year teacher, others highly-experienced (13+ years teaching)
- Class sizes ranging from 18-26 students
- Rural, urban, and suburban school settings
- Participation in the project over multiple years as collaborative partners

Challenges for Teachers

- Ongoing project research (Vo, Forbes, Zangori, & Schwarz, 2015)
- Emphasizing modeling as representation AND sense-making
- Fostering ‘consensus modeling’ discussions
- Supporting students to focus on model-based explanations
- Allowing students to revise ideas over time

Curricular Intervention

- Pre/Post-unit supplemental modeling lessons with student modeling tasks
- Modifications to four unit investigations
  - Use model to predict, interpret observations, and explain
  - Evaluate and revise model
- Teacher-educative elements focused on scientific modeling and water concepts

Professional Development

- 3 years of ongoing support
  - In-class enactment support
  - 2, 5-day summer workshops
- Core elements
  - NGSS and modeling
  - Curriculum-grounded
  - Analysis of student models
  - Reflection on classroom instruction
  - Discourse and sensemaking discussions

For More Information

Cory Forbes

Associate Professor of Science Education

Coordinator, IANR Science Literacy Initiative

School of Natural Resources

University of Nebraska-Lincoln

523 Hardin Hall

3310 Holdrege Street

Lincoln, NE 68583-0995

cory.forbes@unl.edu

Modeling Hydrologic Systems in Elementary Science

MICHIGAN STATE UNIVERSITY | College of Education Department of Teacher Education

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QUEST

Quality Elementary Science Teaching

FOUR EMPHASIS AREAS

5E Learning Cycle

Universal Design for Learning (UDL)

Lesson Design

Formative Assessment

Conceptual Storylines

PRACTICUM-BASED PROFESSIONAL DEVELOPMENT MODEL

Week one: Content & Pedagogy

Week Two: Practicum

DESIGN RATIONALE

"The classroom is a powerful environment for shaping and constraining how practicing teachers think and act. Many of their patterns of thought and action have become automatic—resistant to reflection or change. Engaging in ~~learning~~ [*teaching*] experiences away from this setting may be necessary to help teachers 'break set'—to experience [*teaching*] things in new ways" (Putnam & Borko, 2000, p. 6).

IMPLEMENTATION MODEL/RESEARCH DESIGN

Group1 (n=20)

- Summer Week 1: Physics & Pedagogy
- Summer Week 2: Designing & Implementing Instruction (Practicum)
- Academic Year Saturday follow-up sessions

Group 2 (n=20)

- Summer Week 1: Physics & Pedagogy
- Summer Week 2: Designing Instruction only
- Academic Year Saturday follow-up sessions

Comparison Group (n=20)

- No Summer Institute
- No Academic Year Sessions
- Summer 2-day Workshop Subsequent Year

ASSESSING OUTCOMES

What are we assessing?	What tools are we using?
Content Knowledge	Proximal & distal measures – MOSART & unit tests (created and/or modified)
Pedagogical Knowledge	Understanding of the 5E Learning Cycle Universal Design for Learning
Pedagogical Content Knowledge	Content Representation Tool (CoRe) & Lesson Plan Task
Classroom Practice	Classroom Observations
Student Learning	Proximal & distal measures – unit tests (created and/or modified) and state achievement tests

ASSESSMENT CHALLENGES

- Are we impacting content knowledge or more specialized content knowledge for teaching (e.g., conceptual storylines)?
- How are teachers' practices influenced by changes in their local contexts? (grade level, curriculum, state standards, accountability)
- What unanticipated outcomes are valuable to document and examine? (e.g., teacher leadership, collaborative networks, adaptive expertise)

PROMOTING STUDENTS' SPATIAL THINKING IN UPPER ELEMENTARY GRADES USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

INNOVATIVE CURRICULUM IN 5TH GRADE CLASSROOMS

PROJECT OVERVIEW

- 5th grade students
  - Urban setting
  - 3 schools, 7 teachers, 8 Classrooms this year
- Objectives:
  - (1) develop instructional modules that are focused on promoting children's spatial thinking using GIS,
  - (2) measure the impact of these modules on children's thinking and problem-solving.

- Other interests include:
  - Systems thinking
  - Multi-step reasoning
  - Argumentation
  - Collaboration
  - Technology skills
  - Independence
  - Professional Development
  - Gender performance gap

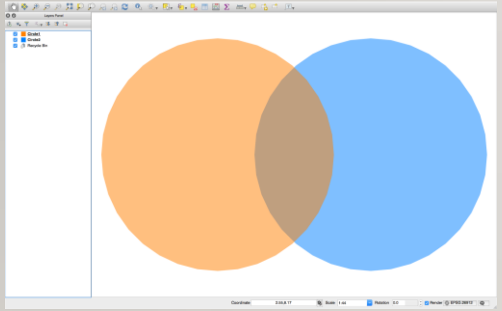
PROJECT OVERVIEW

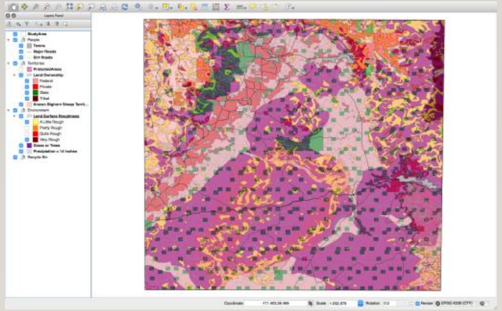
- Components
  - Technology-focused curriculum that uses GIS (Geographic Information Systems)
    - Six week program, with sessions 3-5 days each week
    - Integrates ELA, social studies, and science
  - Intensive teacher training
    - 20 hours of training before school year
    - Continued technology and curriculum support through entire implementation
  - Rigorous Data Collection w/ Pre-Post Design
    - Classroom video from every session
    - Map-based problem assessment (NAEP), CogAT, Interest Questionnaire, Technology and Video Game Play Questionnaire, Cognitive Interview,

CONCEPTUAL FOUNDATIONS

- The relationship between spatial ability and success in STEM disciplines is strong. ✔
- Early intervention can reduce gender differences in children's spatial reasoning ?
- Research has suggested a link between use of GIS and students' spatial ability ?
- Previous research utilizing GIS has been with students in middle school and older ✔
- STEM curriculum must involve students in Science and Engineering Practices, and foster broader aims of independence, collaboration, and argumentation ✔

PROJECT INTERVENTION





- **Module One.** Students learn four "Geoprocessing" tools (Buffer, Intersect, Union, Difference) rooted in set theory as the conceptual foundation for solving spatial (map-based) problems
- **Module Two.** Using a digital depiction of a Venn Diagram, students learn how to use QGIS, a geographic information system, to view and interact with data. Students learn how to use the software to execute the four Geoprocessing tools. Starting in Module Two, students always work with a partner, sharing a computer.
- **Module Three.** Given a set of criteria and a set of map-data in QGIS, students learn how to use the Geoprocessing tools in the software to find a solution to a multiple-part problem
- **Modules Four and Five.** Given a set of resources including a narrative, newspaper clippings, and fact sheets, students are presented an ecological problem. Students must use the resources to determine criteria for solving the problem, then develop a strategy for using GIS and the Geoprocessing tools to find a solution.
- **Module X.** An independent module that can be implemented anytime once students have completed Module Two, this module presents students with a series of simple problems contextualized in the battles of the Revolutionary War. Students must think critically about the use of Geoprocessing tool. Each problem provides students an opportunity use social studies content knowledge and/or prompts critical analysis of the content from a new perspective.

ALIGNMENT BETWEEN INTERVENTION AND CONCEPTUAL FOUNDATIONS

Conceptual Foundations

- There is a strong relationship between spatial ability and success in STEM fields
- Research has suggested a link between use of GIS and students' spatial ability
- Previous research utilizing GIS has been with students in middle school and older
- Early intervention can reduce gender differences in children's spatial reasoning
- STEM curriculum must involve students in Science and Engineering Practices, and foster broader aims of independence, collaboration, and argumentation

- We implemented a 6-week, GIS-based curriculum in 5th grade classrooms – earlier than previous research
- Our intervention focused on spatial ability, which is typically unaddressed by existing curricula, through use of GIS and spatial representation of mathematic principles (set theory)
- Through careful scaffolding and an inquiry model, our intervention also addressed the NGSS Science and Engineering Processes, while striving to foster independence, collaboration, argumentation, confidence, and computer competence – these broader aims are a common current through all STEM-focused education
- Ultimately, we sought to examine the viability of GIS as an instructional tool with younger students, while determining if such an intervention would impact crucial skills for future STEM success

FOCUS on energy

Preparing Elementary Teachers to Meet the NGSS Challenge

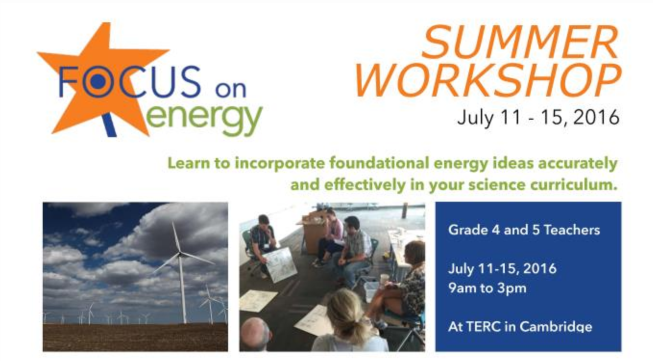
Sara Lacy, TERC
Stamatis Vokos, SPU
Roger Tobin, Tufts
Nathaniel Brown, BC

Goal: *to provide teachers and students with **resources**, a **framework, and representations** to reason about forms and flows of energy in all disciplines of science and in phenomena they encounter in everyday life.*

Year 2 of a 4-year development project

A System of Resources

for teaching and learning about energy in elementary school.

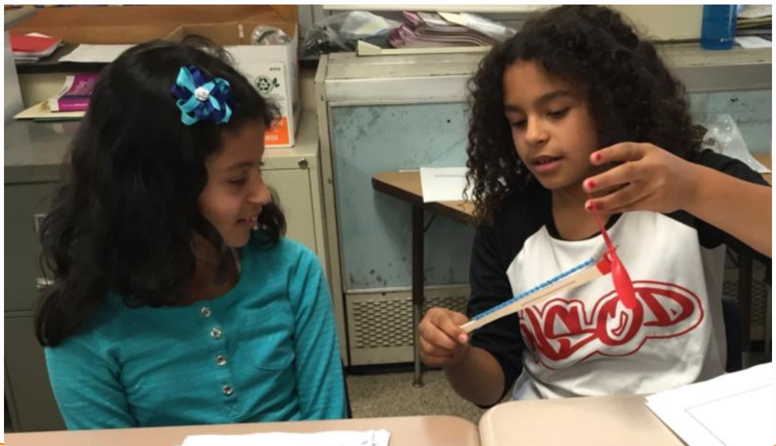


Teacher Professional Learning

Classroom Activities

Web-based Resources

The Energy Tracking Lens



What's happening?

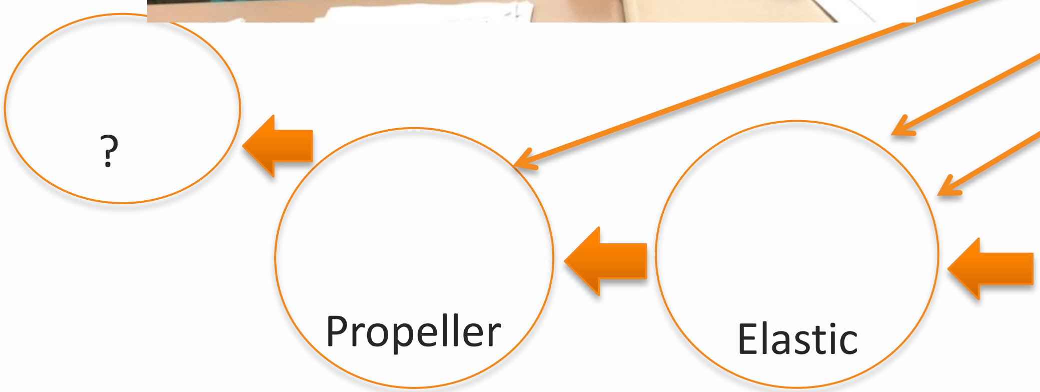
What are the components of the system?

Where are there energy changes?

- *Increase in motion energy*
- *Decrease in elastic energy*
- *Transformation from elastic to motion energy*

Where does the energy come from? Where does the energy go?

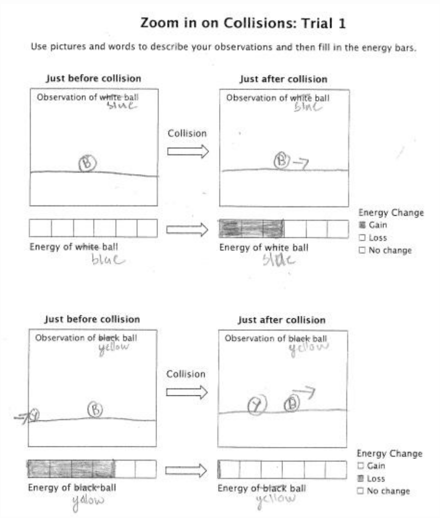
What is the evidence?



Representations

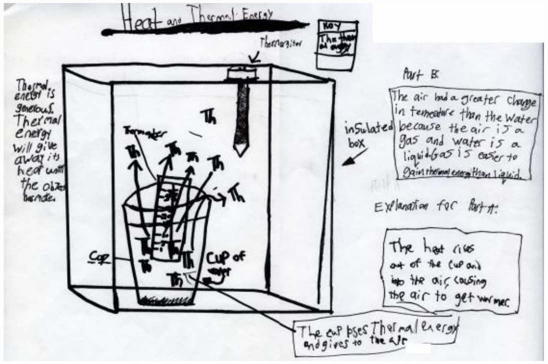
A Critical Tool for Reasoning about Energy

Energy Bars



Energy Cubes

Annotated Drawings



Assessments

Giant Rubber Band Ball: How do you make a giant rubber band ball? Use a lot of rubber bands! Stretch each one around the others. When you cut into the ball, the rubber bands fly into the air.

Entertaining scenarios

FOCUS on energy

Assessments

2. Forms of Energy and Energy Transformation

5	This object can have more than one form of energy at the same time.
4	Form of energy that this object has can change into another form of energy; this is called energy **transformation**.
3	Presence of this object's energy in this form can result in a presence of another form of energy.
2	Some of these objects have (different forms of) energy and existence of these (forms of) energy is not related/dependent to each other.
1	All objects in this item have energy at some point in the context.
0	Not all objects in this item have energy.

Entertaining scenarios

Responses mapped to a model of learning (progress variable)

FOCUS on energy

Assessments

A second after the cut,

Right now after the cut, the rubber bands in the air...

- have energy.
- do not have energy.

After the cut, the rubber bands in the air have energy because...

- they took energy from somewhere.
- they had energy when they were in the ball.

The rubber bands have...

- the same kind of energy before and after the cut.
- different kinds of energy before and after the cut.

Entertaining scenarios

Responses mapped to a model of learning (progress variable)

Students only see appropriate response options

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TERC

DRL-1316762

Collaborative Research: Multimedia Engineering Notebook Tools to Support Engineering Discourse in Urban Elementary School Classrooms

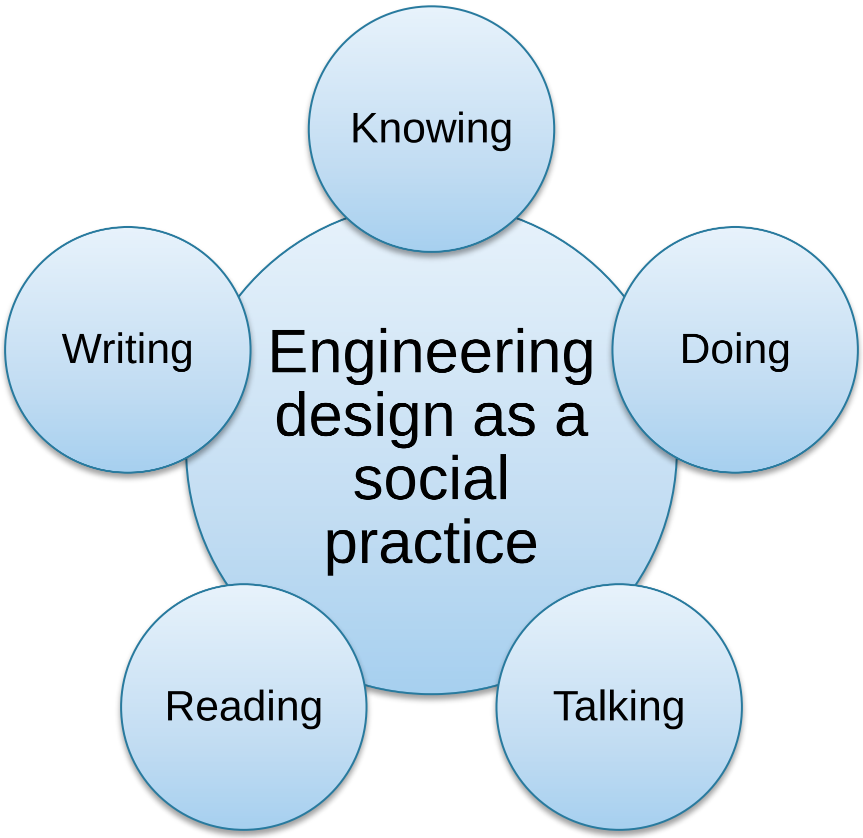
Kristen Wendell, Tufts University
Christopher G. Wright, University of Tennessee Knoxville
Patricia Paugh, University of Massachusetts Boston
Chelsea Andrews, Tufts University
Kathy Wright, Boston Public Schools
Christine Valenti, Boston Public Schools

Project Phases

- **Year 1 (Spring 2014):** Baseline data of urban elementary students' discourse during Engineering Is Elementary units in TN and MA
- **Years 2 & 3 (2014-16):** Small pilots of possible engineering discourse supports (with and without digital tools)
- **Year 4 (2016-17):** More systematic trials of interventions and digital tools; dissemination strategies

Learning Opportunities Provided by Elementary Engineering

Disciplinary Discourses of Engineering… Ways of:



Seven Urban Elementary Classrooms – Northeast and Central U.S.

How can we describe (to researchers and educators) the Discourses that exist and/or need to be supported during engineering experiences?

NGSS Practices and Academic Communication (Haneda, 2014)

Constructing Explanations and Designing Solutions
The products of science are explanations and the products of engineering are solutions.

Engaging in Argument from Evidence
Argumentation is the process by which explanations and solutions are reached.

Obtaining, Evaluating, and Communicating Information
Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity.

- http://ngss.nsta.org/PracticesFull.aspx

Discourse Supports

1 (Paper-and-Pencil) – Across-Team Critique Protocol with Whiteboarding
critique across different student design teams (piloted with Ms. Harrison's water filter unit)

2 (Paper-and-Pencil/Multimedia) – Within-Team Critique Protocol with Plus/Delta Feedback
critique within the same student design teams (piloted with Ms. Valenti's simple machines unit)

3 (Paper-and-Pencil) – Designing for Others to Build
create representation of design for another team to fabricate (piloted with Ms. Wright's literature-based towers unit)

4 (Multimedia/Digital) –Design Portfolios
compile portfolio of design documents and reflection interviews AFTER completing an engineering design product (piloted by Ms. Valenti after FOSS Motion & Design unit)

5 (Multimedia/Digital) –Design Process Documentation
create digital notebook DURING an engineering design process (piloted with Ms. Wright's knee braces unit and with one team in Ms. Valenti's simple machines unit)

6 (Paper-and-Pencil) – Scaffolds for Engineering Explanations
Short instructional module and graphic organizers to support students in telling each other about the materials, properties, and functions of their engineering designs

7 (Paper-and-Pencil) – "Neutral Question" Critique Protocol for Whole-Class
Mini-lesson adapted from Project Zero Arts Critique on how to offer critiques of engineering designs through neutral questions

8 (Multimedia/Digital) – Notebooking Cards
Interactive and self-selecting tools for students to utilize DURING during planning, building, testing, and redesign stages

Digital Notebooking Cards

8 (Multimedia/Digital) – Notebooking Cards

Interactive and self-selecting tools for students to utilize DURING during planning, building, testing, and redesign stages

Problem

Goal: Build a circuit that lights a bulb when water trough is empty

Criteria:
1. Uses trough as switch
2. Closed circuit lights the bulb
3. Switch connection point completes circuit

Constraints:
1. One battery
2. One bulb
3. One bag of materials, no trading

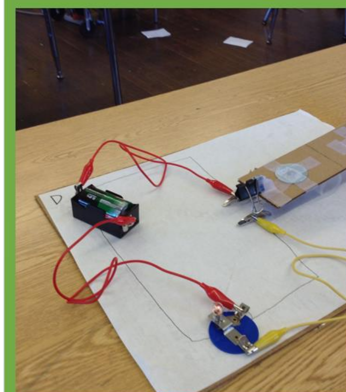
Test:

Pull out water beads to represent water level lowering in trough

Pass: switch connection point completes circuit, bulb lights

Fail: switch connection point doesn't complete circuit, bulb doesn't light

Test #



What did you change?

The paper clips where changed for a binder clip

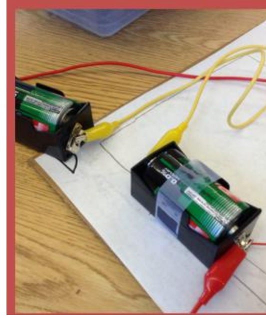
What was the test result?

It works

Any ideas why?

The circuit was complete

Issues



What's not working?

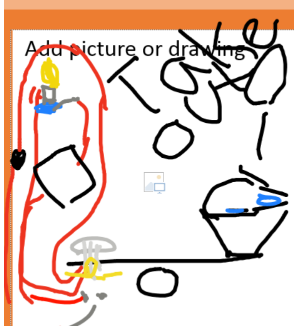
It worked but it wasn't powerful so we added a second battery so it was more bright and a bit louder

Any ideas why?

Too much energy for one battery to handle

Ideas

Add picture or drawing



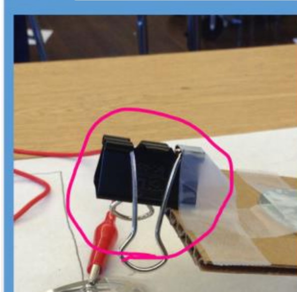
Add picture or drawing

We would take water out and then it would fall and the paper fastener would touch the wire

Material: Binder clip

Feature

Name: Binder clip



Description:

A normal binder clip

Function:

Completes circuit

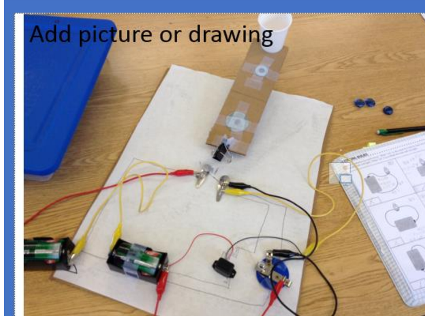
Pros & cons:

Pro. Conductor

Con. Bulky

Final design

Add picture or drawing



3 wires, 1 lightbulb , 2 battery and 1 homemade switch

Transformative Robotics Experience for Elementary Students (Project TREES)

Ji Shen
Lauren Barth-Cohen
Moataz Eltouhky
University of Miami

TREES: *Overview*

Goals and Objectives:

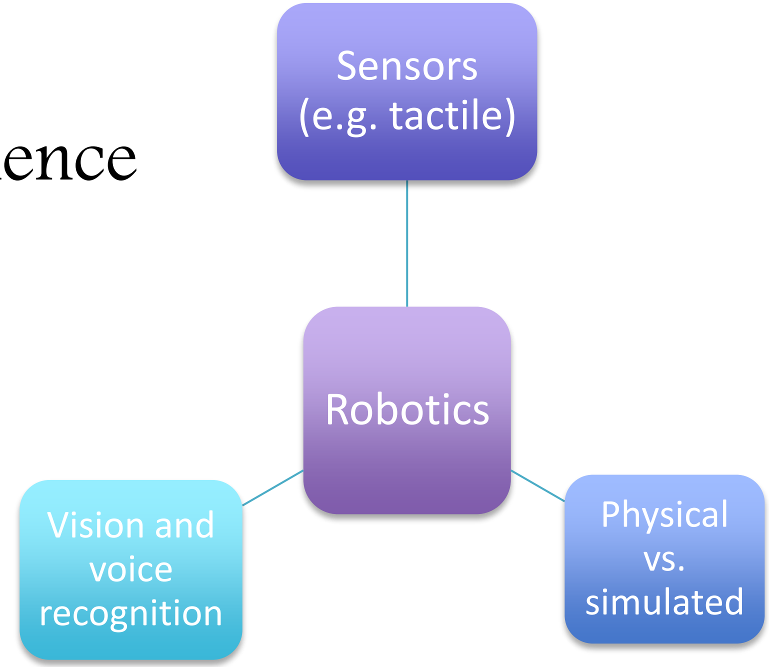
- help elementary students develop ***computational thinking*** through a robotics/programming curriculum using a humanoid robot platform - NAO.

Setting:

- A Title I public elementary school in Broward, FL.
  - Pilot (2015): 10-weeks of instruction, one 5th grade class (n=22)
  - R2 (2015-2016): six 5th grade classes (n≈130)

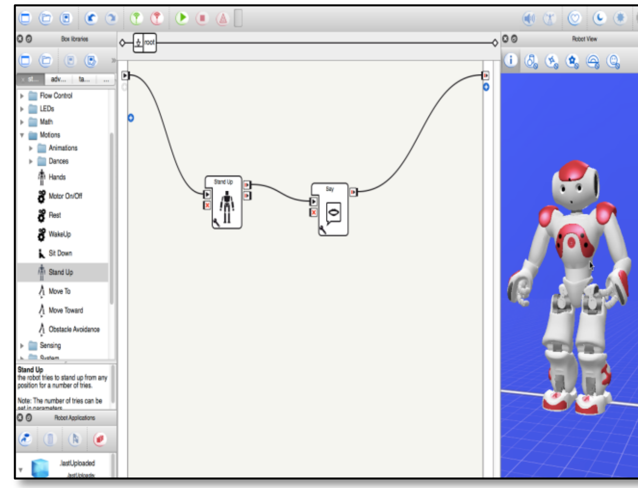
TREES: *Curriculum*

- Under the underlying theme of humanoid robotics, computer science concepts were woven in the curriculum.
  - Chapters 1~5: fundamentals of robotics and programming.
  - Chapters 6~7: the basics of the humanoid robot's programming software.
  - Chapters 8~14: different capabilities of the robot and how to program the robot to utilize each of these capabilities.



TREES: *Implementation*

- One session (~1 hour) per week during the school day
- Each student has their own laptop with the robotics software; One robot shared among all classes
- During class students write code, test it on the simulation, and then run it on the physical robot
- Curriculum includes end of unit mini-projects and a final project.
- Work in small groups and present their projects in a school-wide assembly.



TREES: *Challenges*

- Assessing computational thinking
  - Assessing CT at the elementary level
  - Pre/post
  - Identifying computational thinking in programming
- Implementation
  - motivate different stake holders (e.g., teachers, administrators, IT person) under the standardized testing pressure
  - prepare and support teachers to be 'ready'
  - technical issues

Knowledge Assets to Support the Science Instruction of Elementary Teachers

ASSET

A Problem

A Vision

A Challenge

A Solution

A Problem

- Demands of the NGSS
  - 3D learning, practices
  - Rearranged topics
- Lack of aligned instructional materials

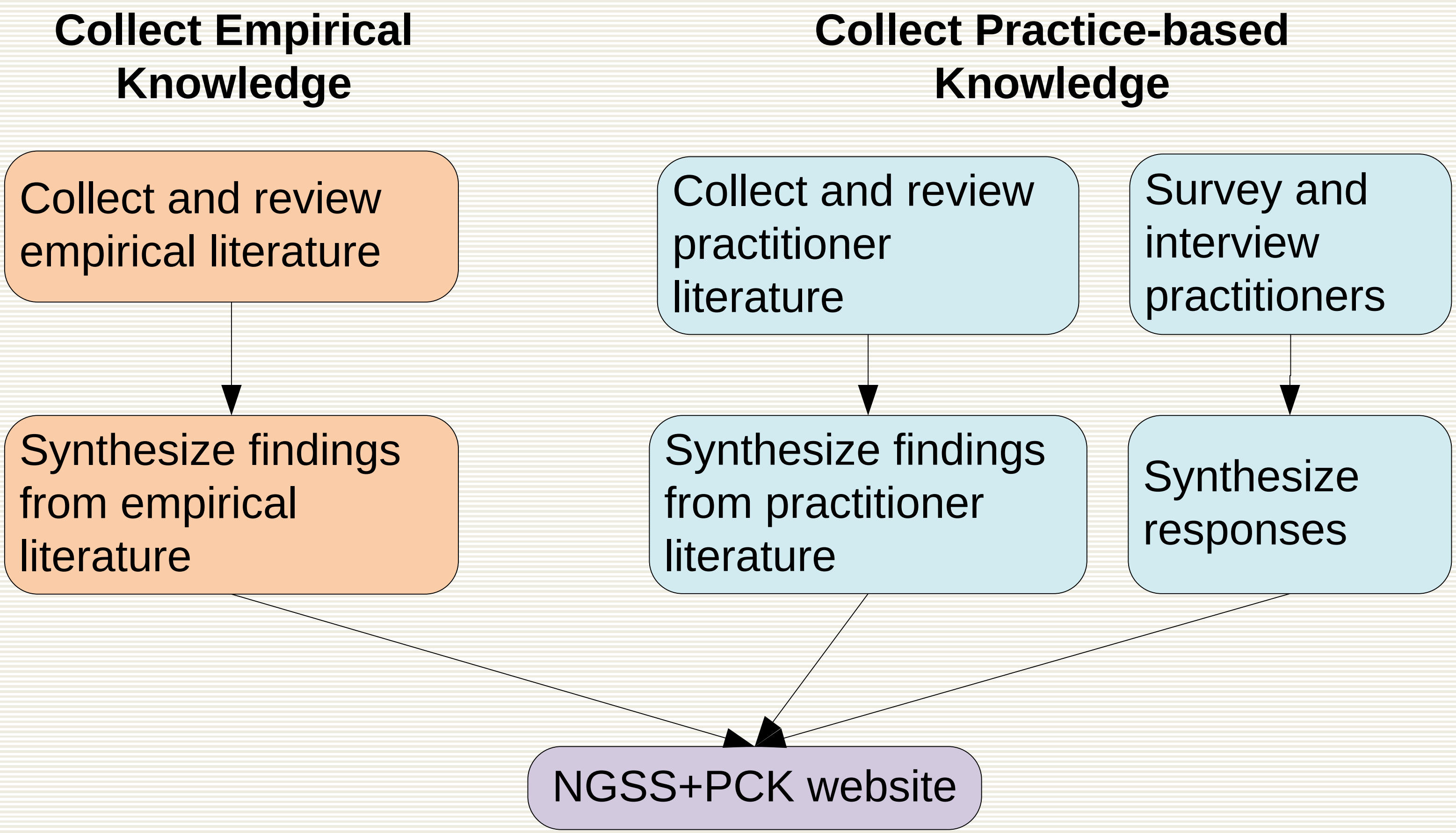
A Vision

- NGSS+PCK
- A web-based, stopgap resource until teachers have access to aligned instructional materials
- Knowledge **organized for use by teachers**

A Challenge

- PCK for many NGSS topics is thin
- PCK that incorporates 3D learning is even thinner
- Available PCK is not organized for use by teachers

A Solution


Collect Empirical Knowledge
Collect Practice-based Knowledge
Collect and review empirical literature
Synthesize findings from empirical literature
Collect and review practitioner literature
Survey and interview practitioners
Synthesize findings from practitioner literature
Synthesize responses
NGSS+PCK website