CAREER: Building Productive Uncertainty into Elementary Science Investigations

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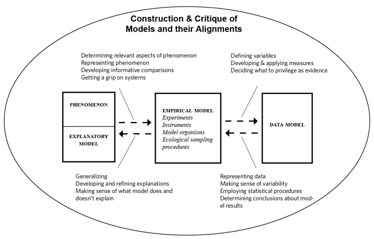
Abstract

This project explores how to design and implement classroom science investigations that make productive use of the uncertainty that scientists experience as they conduct investigations. We have developed a framework that situates empirical activity in a modeling enterprise, and identifies forms of uncertainty common to investigations. We used the framework to co-design, analyze, and re-design investigations with early (Grade 2) and upper elementary (Grade 5) teachers. The poster presents and illustrates design tools emerging from this work. These support curriculum designers and teachers to implement the uncertainty in science investigations in nuanced ways, making choices based on the specific investigation's affordances, conceptual goals, and student resources.

Conceptual Framework: Investigations Within a Modeling Enterprise

We treat the investigation as part of a modeling enterprise that involves developing and aligning models of different kinds and purposes. The gaps between models present recurrent non-obvious decisions (uncertainty) and, as such, are sites for scientific practice.


Construction & Critique of Models and their Alignments
Determining relevant aspects of phenomenon
Representing phenomenon
Developing informative comparisons
Getting a grip on systems
Defining variables
Developing & applying measures
Deciding what to privilege as evidence
PHENOMENON
EXPLANATORY MODEL
EMPIRICAL MODEL
Experiments
Instruments
Model organisms
Ecological sampling procedures
DATA MODEL
Generalizing
Developing and refining explanations
Making sense of what model does and doesn't explain
Representing data
Making sense of variability
Employing statistical procedures
Determining conclusions about model results

Methods

The researcher-teacher team followed an iterative process of (1) developing conjectures, (2) working together on a tangible product or process (here lesson plans that supported students to engage with uncertainty), (3) analysing and reflecting on implementation, and (4) revising materials and tools to support other teachers. Researchers and teachers took on different roles, but purposefully blended typical researcher/teacher responsibilities in data analysis and teaching. Each of four focal investigations was implemented 3-4 times. Data was logged, then analysed using project protocols to identify (1) what kinds of uncertainty were evident; (2) how uncertainty was made public; and (3) whether and when uncertainty supported productive interactions. These analyses formed the basis for redesigning lessons and tools, reflecting on, and refining the group's working processes.

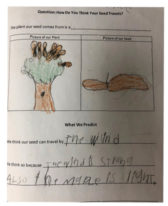
EXAMPLE: WIND DISPERSAL INVESTIGATION

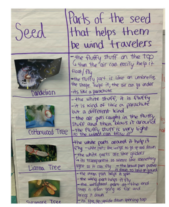
We illustrate engaging children with productive uncertainty in science investigations using a seed dispersal investigation conducted with second grade children (7 & 8). The investigation addresses second grade standards related to developing models, planning and conducting investigations, ecological relationships, and form-function thinking.

ENGAGING WITH THE PHENOMENON AND DEVELOPING IDEAS TO TEST

Children:

- Read a book about seed travel.
- Make predictions about their seeds, considering seed and its parent plant.
- Watch a video of wind travel and describe the features that help seeds travel by wind.

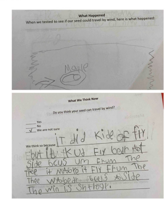




PLANNING AND CONDUCTING AN INVESTIGATION

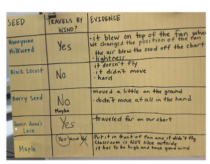
Children:

- Discuss how to use a fan to test their ideas.
- Test together with an electric fan and chart paper to mark travel.
- Write what they think now and why.



MAKING CLAIMS AND ENGAGING IN SENSEMAKING

Children share claims and evidence from their wind test, beginning with seeds that are more obvious and moving to the maple seed last.



Ms. N: So what did you (maple seed group) conclude?
Mira: I think it doesn't fly because we dropped it and it didn't fly.
Ms. N: Is everyone in agreement that the maple seed definitely does not travel by wind?
Ari: Me and Gregory think it does.
Gregory: It has to have a certain amount of wind.
Michael: It has to be- you know how the maple seed first starts in a tree- it has to be somewhere high...
Ari: And so like, it is not exactly like outside, so how do you know it actually doesn't, because I've seen it live so we think yes & no.

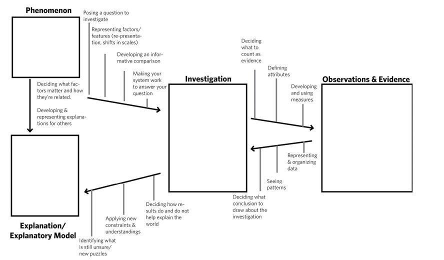
DEVELOPING A NEW TEST

Many classes propose a new test of dropping the maple seed from the second floor window and testing both single and double seeds to see how far they travel. Others discuss and read about the maple seed.

TOOLS

INVESTIGATION FRAMEWORK

We have translated the conceptual framework into a tool, the "Zig-Zag," that we use to identify forms of uncertainty present in particular science investigations.


Phenomenon
Posing a question to investigate
Representing factors/features (re-presentation, shifts in scales)
Developing an informative comparison
Making your system work to answer your question
Deciding what factors matter and how they're related.
Developing & representing explanations for others
Investigation
Deciding what to count as evidence
Defining attributes
Developing and using measures
Observations & Evidence
Representing & organizing data
Seeing patterns
Deciding what conclusion to draw about the investigation
Deciding how results do and do not help explain the world
Applying new constraints & understandings
Identifying what is still unsure/new puzzles
Explanation/Explanatory Model

DESIGN STRATEGIES & MAKING DESIGN BETS

We have developed a description of strategies for incorporating uncertainty and under what conditions they can be useful.

Strategy	Example	When it might be useful
Try to get rid of it	Give students closed vials for an investigation on whether water increases or decreases in weight when frozen.	When we can legitimately do this, and we think the uncertainty is too much or not worth addressing at this time.
Make and explain a choice	Provide a constant source of moisture in an investigation of effects of light on plants.	When we think the uncertainty is not worth grappling with, and the reasons for the choice are within students' understanding.
Support students to think and discuss during planning; e.g., offering two choices, outrageous claim	Ask if tape is a good material to use to see if a seed is good at traveling by sticking to animals. Compare two ideas for investigating whether water weighs more when it freezes: measuring the same water before and after freezing or comparing liquid water to the same volume of water that's been frozen.	When uncertainty is important and within the range that students will be able to grapple with productively and get where we want them to (approximately) before the investigation in order to get data that will help us make progress.
Allow students to plan something such that the investigation will push back and do something unexpected; then iterate.	Students find that a maple seed does not move by wind when they put it in front of a fan and decide they need to replan their test to drop the seed from the height it would be on the tree.	When students wouldn't know to plan something ahead of time, uncertainty is productive, and we think that the result will be surprising and lead them to discuss and re-plan in relation to something we care about.
Allow students to do something differently than each other so that they come to different conclusions or communicate	Students argue different plant conditions are more successful because they focus on different evidence, such as height of a plant or whether it has seedpods; students disagree	When the uncertainty is productive and there aren't so many sources of uncertainty that students will just conclude that they "did different stuff" or "see different things."

IMPLEMENTATION TOOLS

We are refining a set of implementation tools that include routines for supporting students to plan investigations and make sense of evidence, as well as assessment tasks and "look-fors."

Planning Investigations Routine

Teacher Preparation Before Lesson

- Decide what decisions **students** will discuss/make about what materials to use, how to use them, and what to count as evidence.
- Decide what decisions **you** will make for students and how you will communicate the rationale to students.

For the decisions you want students to make or discuss, consider:

- Is it okay if they do different things in the investigation or come to different conclusions?
- Will they be able to share results, learn from each other, and iterate their thinking?

Component	What Students Are Doing	Specific Teacher Strategies to Consider
Establish a shared question or goal	Developing a shared understanding of the phenomenon of study and generating questions that will motivate the investigation.	• Make a link to students' ideas and questions in previous lessons to establish a focus for this investigation • Engage with a shared book, photograph, or video to provide a visual representation of the phenomenon that students can refer to throughout the investigation • Write the investigation question in a visible space, such as on a piece of chart paper; keep it up and use as a reference throughout the planning discussion.
Introduce the investigation as a tool for making progress on student questions	Understanding the rationale for the investigation and feeling a need to figure something out.	• Establish a disagreement or uncertainty that motivates the need to do an investigation by eliciting students' tentative explanations or predictions: *"What do you think happens when…?"* • Name and orient to students' questions, disagreements, or uncertainties: *"It seems like we have a lot of different ideas about [X]"* • Establish that the investigation is a tool for making progress on understanding the phenomenon: *"We can design an investigation to help us figure this out."*
Introduce or discuss what is already set in the investigation	Developing an understanding of the boundaries of their investigation.	• Introduce the materials and explain the rationale for the choices you have made about what students will do. • Help students connect parts of the investigation to aspects of the phenomenon they are seeking to understand.
Introduce and/or discuss decisions students will make in the investigation	Exploring ideas about what materials to use, how to use them, and/or what to pay attention to in the investigation.	• Help students attend to decisions about what materials to use, how to use these materials, and what to pay attention to as evidence. • Use structures to support decision-making and discussion, such as: ○ Comparing two choices and have students justify which to choose ○ Partner planning with a public comparison of strategies or feedback ○ Putting forward an "outrageous idea" for the purpose of eliciting disagreement and justification • Link the discussion back to the question of how choices will help students figure something out or make progress on answering their questions. • Support students to play the investigation forward: *"If X happens in our investigation, what will that tell us?"*

Focus	May need further support	What we are hoping for...	Wow!
Claim: *Students can make a claim about how a seed could travel (or travel best)*	Claim is not plausible.	Plausible claim based on the features of the seed. Also found in the poster.	•Names more than one plausible way the seed travels •Claim compares likelihood •Claim identifies both plausible and implausible methods.
Evidence: *Students can draw on evidence from empirical tests to develop and support their claim.*	Doesn't provide evidence or evidence doesn't appear to be connected to the claim.	Cites evidence from a test.	•Cites evidence from multiple tests to strengthen argument •Makes a comparison with other seeds to strengthen use of evidence •Uses evidence to explain why they changed their mind after a test. •Tells why something is evidence
Explanations of how or why the seed can travel in a particular way: *Students can connect features of the plant or its environment to the seed's travel method(s).*	Restates claim and/or evidence without naming a feature that will help the seed travel. Or ONLY cites generic features similar to what children attended to before the work began: e.g., lightness or smallness for flying.	Describes a feature and tells how it helps the seed travel. and/or Cites features of the parent plant or environment that allow the seed to travel in a particular way.	•Describes the work that the seed feature does or what about that feature makes a difference. •Includes multiple explanatory mechanisms in explanation. •Describes how they revised or refined the explanation over time (made broader, narrower, deeper).
Representing ideas in scientific drawings: *Students use drawing to express ideas and can apply representational strategies to do so.*	Picture and explanation do not match.	Picture supports the explanation in the claims sheet. It: Shows a feature of the seed that helps it to travel. OR Uses at least one representational strategy (Zoom-in, label, arrows, different viewpoints (e.g, inside the seed)).	Picture includes explanatory work; it "shows how things are happening" This might include: •How the seed comes off the parent plant. •Hidden mechanisms such as wind/force made visible.
Uncertainty: *Student recognizes and discusses strategies to manage uncertainty in making a claim based on an empirical investigation.*	No uncertainty is evident in Claims Sheet. Poster shows no uncertainty. or Student hedges but doesn't explain why they might be uncertain.	Student indicates at least one reason their claim might not be totally "right," including (1) differences between the test and conditions outdoors, (2) uncertainty about conditions outdoors (3) uncertainty about data collected and what it means. And/or Student poses a question they're now curious about	•Makes statements of likelihood based on justifications about the outdoors and performance of seed in tests. •Names conditions under which the claim holds true. •Can propose a specific way to improve the investigation or a next investigation that addresses a problem identified/reason they are not sure.

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