Data Explorations in Ecology: Students' Understanding of Variability and Use of Data in Environmental Citizenship

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ASTE Annual Meeting
January 9, 2015
Acknowledgements

• Teacher participants
• Student participants
• National Science Foundation, NSF Grant DRL-1020186
• Cary Institute Scientists
  – Dave Strayer
  – Stuart Findlay
  – Bill Schlesinger
What’s Ahead

• Data literacy and environmental citizenship
• A framework for data literacy practices
• Student proficiency
• Teacher implementation
• PD Implications
Data Literacy & Environmental Citizenship

• The **promise** of Data Literacy as both
  – An **endpoint** or educational goal ... an essential component of environmental citizenship
  – A **means** or educational tool ... for authentic, science-based engagement with the world.

• The **challenges** for Data Literacy
  – Student interest (motivation, efficacy), engagement and proficiency
  – Teacher KSA’s, curricula, accessible datasets and exploration tools, research about discipline-based data literacy, data literacy assessment tools
Locally Relevant Socio-Ecological Issues

Hydro Fracking

Fight Back!

Attacking the Frack!

NEW YORKERS
AGAINST FRACKING
NYAGAINSTFRACKING.ORG

Salt Pollution
Next Generation Science Standards – Science Practices

**BOX 3-1**

**PRACTICES FOR K-12 SCIENCE CLASSROOMS**

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

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Data Literacy Skills

Data Exploration in Ecology Project (DEEP)

Helping high school teachers and students make sense of data they collect themselves and data they get from other sources.
An Evidence- and Reasoning-Based Critique and Inquiry Framework
An Evidence- and Reasoning-Based Critique and Inquiry Framework
1. Identify variability
2. Understand sources of variability
3. Reduce variability
4. Calculate indices, etc.
5. Choose data

1. Understand implications of variability for inferences
2. Identify and create different types of representations
3. Choose appropriate representation
4. Interpret representations
5. Evaluate representations

1. Use multiple types of data
2. Choose data to support claims
3. Combine evidence appropriately
4. Critique choices and synthesis of evidence in arguments

1. Construct an argument with evidence & reasoning
2. Communicate argument
3. Make evidence based recommendation
4. Constructing an argument

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**DATA**

- **Raw Data**
- **Derived Data**
- **Representations**

**EVIDENCE**

- **Filters & Synthesis**
- **Arguments**

**INFORMATION**

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**EVIDENCE-BASED INQUIRY**

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**EVIDENCE-BASED CRITIQUE**

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**REASONING**

---

**Questions**

**Design & Impl.**

**Manip.**

**Analysis & Summary**

**Synthesis**

**Commun. & Apply**

**Action**
Research Questions

1) What do students know, and what are they able to do, in terms of data literacy skills, specifically those related to variability in data.

2) What supports and constrains teachers’ implementation of instruction that targets data literacy skills.
Methods – Student Research

• Recruit 14 HS teachers
• Engage over 600 student participants in 5-8 lesson modules exploring issues – hydrofracking, salt, etc.

• Administer assessments
  – pre- and post-tests of student’s data exploration and critiquing proficiency, attitudes and perceptions of the learning experience
  – end-of-module “Critique and Inquiry Assignments” in response to arguments from the scientific or popular press about issues
• Code responses for key progress variables of interest
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- Design & Impl.
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DATA

EVIDENCE

INFORMATION

EVIDENCE-BASED INQUIRY

EVIDENCE-BASED CRITIQUE

REASONING

Questions

Raw Data

Derived Data

Representations

Filters & Synthesis

Arguments

Action
What do students understand about the concept of *variability* in data exploration?

• Recognition
  – can judge relative amounts of variability

• Reasoning
  – can explain their judgments about variability
  – can discuss sources of variability

• Importance
  – appreciates the importance of variability
70-80% of students recognize variability

1. Look at the temperature data at different times within EACH of the three periods. Compare them and then decide which period shows the most variability. Explain why you picked that period.
Student-Listed Sources of Variability

- **Induced** = errors or variability introduced in data collection, processing
- **Real** = variability in the phenomena or parameter being measured
- **Anthropogenic** = variability caused by human impacts on the environment

N = 252 students
Sources of Variability

- Spatial Measurer
- Devices
- Timing
- Processing
- Natural
- Seasons
- Pollution
- Climate
- Human Presence
- Water
- Biotic

Percent of Responses

September 2012
May 2013

N = 698 responses
Why is it important to think about variability in a set of data?

Limited Reasoning
• Answers a question
  – *Maybe so that you can answer the questions asked*

Ecological Reasoning:
• Explain ecosystem processes:
  – “The variability of data could help to explain a natural cycle and to understand how the ecosystem works..”
Why is it important to think about variability in a set of data?

Quantitative reasoning:

• **Shows changes in dataset:**
  - *Variability is important because it shows that the data wasn't the same over a period of time*

• **Helps evaluate data:**
  - *The variability is important because there are many factors to change your results that cause variability*
  - *To know how accurate the data is.*

• **Helps interpret data/support/make a claim:**
  - *The less variability in a set of data, the more accurate the information will be.*
Importance of Variability

- 30.2% explains ecosystem processes and natural cycles
- 22.3% shows changes in a dataset
- 17.2% answers a question (general)
- 17.2% helps evaluate data/limits of research
- 9.8% helps interpret data or make/support claim
- 3.3% IR/IDK/DNA/Vague

N = 215 students
Conclusions – Question 1 (students)

• Students are able to identify variability, but are limited in their ability reason about or to explain it.

• Students think of real sources of variability more often than induced sources of variability.
  – But responses depend on the context of the question.

• Students are able to use graphs as evidence to critique claims related to environmental issues.

• “Hot Button” issues (e.g., Hydrofracking in NY) make elicit less use of sophisticated data literacy skills than less controversial issues. – data not shown
Research Questions

1) What do students know, and what are they able to do, in terms of data literacy skills, specifically those related to variability in data.

2) What supports and constrains teachers’ implementation of instruction that targets data literacy skills.
PD Model

• Professional Learning Community (PLC) of HS teachers, scientists, educator

• Authentic ecology, data literacy and issues-based learning, with reflection

• Sustained PD over time – summer & school year

• Educative materials that embody key pedagogies
  – Scaffolded skill development
  – Inquiry combining first and second hand data
  – Supporting Evidence and Principle-Based Reasoning (E&PBR)
  – Culminating performance assessment of both C&I

• Based on a Critique and Inquiry Framework
Methods – Teacher Research

• 14 High School teachers
  – 7 Case Study - 3 module, 4 infusion

• Teacher Surveys
  – 6 per teacher, anonymous, by project evaluator

• Teacher Interviews
  – Mid-year (Case Study Teachers), by staff
  – End of year, anonymous, by project evaluator

• Teacher Logs
  – 1 per module implemented

• Teacher Reflections
  – Mid-year (Case Study teachers) and End-of-year

• Classroom Observations
  – 3 per Case Study “module” teacher, by staff
### Teacher Progress Variables

1) Teachers’ **implementation** of the modules and use of the data literacy teaching practices

2) Factors **supporting** implementation

3) Factors **constraining** implementation

4) Teachers’ data exploration knowledge, skills and attitudes
   - a. Data literacy skills
   - b. Motivation
   - c. Self-Efficacy
<table>
<thead>
<tr>
<th></th>
<th>Key Data Literacy Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Explicit learning about variability</td>
</tr>
<tr>
<td>2.</td>
<td>Evidence and principle-based reasoning</td>
</tr>
<tr>
<td>3.</td>
<td>Connecting their learning to the real world</td>
</tr>
<tr>
<td>4.</td>
<td>Making and interpreting representations</td>
</tr>
<tr>
<td>5.</td>
<td>Manipulating raw data</td>
</tr>
<tr>
<td>6.</td>
<td>Synthesizing and critiquing arguments</td>
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<tr>
<td>7.</td>
<td>Formative assessment</td>
</tr>
<tr>
<td>8.</td>
<td>Metacognitive reflection about data literacy</td>
</tr>
<tr>
<td>Practice Category</td>
<td>Never</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Exploring Variability</td>
<td></td>
</tr>
<tr>
<td>Consider and discuss sources of variability</td>
<td>0</td>
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<tr>
<td>Base confidence in claims on variability</td>
<td>4</td>
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<tr>
<td>Math/Stats Practices</td>
<td></td>
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<tr>
<td>Process raw data (sums, averages, indices)</td>
<td>0</td>
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<tr>
<td>Use statistics to describe a relationship</td>
<td>4</td>
</tr>
<tr>
<td>Metacognition Practices</td>
<td></td>
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<tr>
<td>Reflect on data knowledge and skills</td>
<td>2</td>
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<tr>
<td>Representations Practices</td>
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<tr>
<td>Represent/analyze data w/ tables, graphs</td>
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<tr>
<td>Discuss limits of different representations</td>
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<tr>
<td>Evidence Based Reasoning Practices</td>
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<tr>
<td>Explain reasoning for a critique or claim</td>
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</tr>
<tr>
<td>Use data from others to support a claim</td>
<td>0</td>
</tr>
<tr>
<td>Inquiry Teaching Practices</td>
<td></td>
</tr>
<tr>
<td>Answer open-ended questions</td>
<td>0</td>
</tr>
<tr>
<td>Design and conduct scientific investigation</td>
<td>0</td>
</tr>
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</table>
Mean Self-Reported Use of Key Data Literacy Practices - Own Module

Water Boatman
Green Darner
Mayfly
Damselfly
Cicada
Ambush Beetle
Katydid

Not at All            A Little           Somewhat             A Lot
## Overall Implementation of the Practices (DEEP Modules)

<table>
<thead>
<tr>
<th>Students are engaged in ...</th>
<th># possible</th>
<th>% done</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explicit learning about variability</td>
<td>191</td>
<td>52%</td>
</tr>
<tr>
<td>2. Evidence and principle-based reasoning</td>
<td>172</td>
<td>60%</td>
</tr>
<tr>
<td>3. Connecting their learning to the real world</td>
<td>169</td>
<td>43%</td>
</tr>
<tr>
<td>4. Making and interpreting representations</td>
<td>112</td>
<td>68%</td>
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<tr>
<td>5. Manipulating raw data</td>
<td>87</td>
<td>43%</td>
</tr>
<tr>
<td>6. Synthesizing and critiquing arguments</td>
<td>34</td>
<td>82%</td>
</tr>
<tr>
<td>7. Formative assessment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Metacognitive reflection re: data literacy</td>
<td></td>
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Students design or discuss redesigning a study to reduce error.

Students consider and discuss sources of variability.

Students base their confidence in findings or claims on the amount of variability in data.

Students explore different data sets to compare variability.

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Hydrofracking Module - Teachers' Reported Implementation of Practices Related to Variability

- Students design or discuss redesigning a study to reduce error: Total Possible: 45, Implemented: 20
- Students consider and discuss sources of variability: Total Possible: 15, Implemented: 5
- Students base their confidence in findings or claims on the amount of variability in data: Total Possible: 20, Implemented: 10
- Students explore different data sets to compare variability: Total Possible: 10, Implemented: 5

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Salt Module - Teachers' Reported Implementation of Practices Related to Variability

- Students design or discuss redesigning a study to reduce error: Total Possible: 35, Implemented: 15
- Students consider and discuss sources of variability: Total Possible: 10, Implemented: 5
- Students base their confidence in findings or claims on the amount of variability in data: Total Possible: 20, Implemented: 10
- Students explore different data sets to compare variability: Total Possible: 10, Implemented: 5
Teacher Described **Constraints** to Implementation (all data)

- **Time**: 32%
- **Student KSAs**: 9%
- **DE Skills**: 10%
- **Curriculum integration**: 18%
- **Access to Data**: 22%
- **Access to resources**: 6%
- **Content knowledge**: 3%

of 243 total utterances
Teacher Described **Supports** to Implementation (all data)

- Student KSAs - data collection: 19%
- Participation in a PLC: 16%
- Working with Cary scientists: 14%
- Engagement in PD activities: 12%
- PD provider support: 10%
- Curriculum materials: 10%
- Teacher learning: 8%
- Involvement in module development: 7%
- Timing of the PD workshops: 4%

of 157 total utterances
Teacher Described **Motivations to Teach DE** (all data)

- **24%** of 62 total utterances
- **24%**
- **23%**
- **15%**
- **11%**
- **3%**

- **DE makes science lessons more authentic**
- **DE is interesting or enjoyable for students**
- **DE skills are important**
- **Teacher learning**
- **Teaching about DE is interesting or enjoyable**
- **Being treated like a professional**
Teacher Described **Self-Efficacy** Regarding Teaching About DE (all data)

- 61% of 54 total utterances
- **Teachers’ understanding of how to implement DE focused instruction**
- **Teachers’ comfort and confidence in their own DE knowledge and skills**
Conclusions – Question 2 (teachers)

• Teachers vary in their use of data literacy practices
  – First hand data collection >> processing, analyzing data
  – Making representations common, > critiquing
  – Reasoning about variability less common
  – Foster metacognition and quantitative reasoning rare

• Factors that support and constrain practice vary
  – PD and educative materials can increase use of certain practices for certain teachers
  – Time is limiting, especially for low implementers
  – Teachers’ and students data literacy skills can be limiting
  – PD builds self efficacy, and proficiency in data literacy which, in turn, may support improved/sustained implementation

• Teacher motivations reflect importance of data literacy
Data Literacy & Environmental Citizenship - revisited

• The **promise** of Data Literacy as both
  – An **endpoint** or educational goal ... an essential component of environmental citizenship
  – A **means** or educational tool ... for authentic, science-based engagement with the world.

• The **challenges** for Data Literacy
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Questions?
Teacher Described **Constraints** to Implementation by Individual Teacher

- **Content Knowledge**
- **DE Skills**
- **Curriculum Integration**
- **Access to Data**
- **Access to Resources**
- **Student KSAs**
- **Time**
Teacher Described **Supports** to Implementation by Individual Teacher

- **Timing of the PD**
- **Involvement in module development**
- **PD provider support**
- **Teacher learning**
- **Curriculum**
- **PLC Participation**
- **Engagement in PD activities**
- **Cary scientists**
- **Student KSAs**
Self-efficacy by Teacher (n=27)

Understanding how to implement DE
Their own DE knowledge and understanding
Environmental Citizenship

- Civic or Social Science Literacy
- Ecological or Environmental Science Literacy
- Practical Wisdom, Skills & Action
- Values & Awareness
- Self Efficacy

Cognition

Affect

Action

Knowing

Doing