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

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Acknowledgements

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- Student participants
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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
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

Locally Relevant Socio-Ecological Issues

Hydro Fracking

Fight Back!

Attack the Frack!

New Yorkers Against Fracking

Salt Pollution
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

- Design & Implement
- Manipulate
- Analyze, Summarize & Visualize
- Filter & Synthesize
- Communicate & Apply

- DATA
- EVIDENCE
- INFORMATION

- EVIDENCE-BASED INQUIRY
- EVIDENCE-BASED CRITIQUE

- Raw Data
- Derived Data
- Representations
- Filters & Synthesis
- Arguments

- Questions
- Action

- REASONING
Progress Variables

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
5. Choose data

1. Construct an argument with evidence & reasoning
2. Communicate argument
3. Make evidence based recommendation for action

DATA
- Raw Data
- Derived Data
- Representations

EVIDENCE
- Filters & Synthesis
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INFORMATION

EVIDENCE-BASED INQUIRY

EVIDENCE-BASED CRITIQUE

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
Progress Variables

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DATA
EVIDENCE
INFORMATION

- Raw Data
- Derived Data
- Representations
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- Arguments

- Questions

EVIDENCE-BASED INQUIRY

EVIDENCE-BASED CRITIQUE

REASONING

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
90% 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. (n=310 students)
About 84% of students can list at least one plausible source of variability.

2. List at least two possible causes of the variability in temperature measurements within any given time period.

N = 310 Students
Students identify many sources of variability.
Very few students describe variability in a set of data as providing insight into natural processes.

Why is it important to think about variability in a set of data?

N = 310 students
A local factory owner is trying to get a permit to discharge warm water into the Hudson River. He uses Graph 4 to support his claim that the water temperature of the river is variable, and thus it doesn’t matter if he adds a bit more warm water to the river. Do you agree or disagree with his claim? Explain your answer, referring back to the graphs.

**Temperature (C) of the Hudson River**

![Graph 4](image)

**Graph 3**

![Graph 3](image)
Reasons: Why did students agree or disagree?

- No reason
- Drop in bucket
- Affects ecosystem
- Uncertainty
- Based on data
Attention to data: what did students focus on when they talked about data?

- Trend in presented data: 40%
- Trend and variability: 15%
- Trend, variability, and scale: 5%

N = 59 (students who mentioned data in their answer)
“He used the graph that didn't show the temp. was rising so that he would get permission when it would obviously matter if he used another graph.”

N = 59 (students who mentioned data in their answer)
“The water temperature already was increasing”

N = 59 (students who mentioned data in their answer)
“the hudson has been increasing in temperature but with fluctuations”

N = 59 (students who mentioned data in their answer)
“Graph 4 shows that over a period of four years, the temperature varied greatly. However, if this factory owner had referred to Graph 3, he would see the trend of the increasing temperatures and realize that adding warm water would make a difference.”
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) may 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
### Key Data Literacy Practices

<table>
<thead>
<tr>
<th>Students are engaged in ...</th>
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<tbody>
<tr>
<td>1. Explicit learning about variability</td>
</tr>
<tr>
<td>2. Evidence and principle-based reasoning</td>
</tr>
<tr>
<td>3. Connecting their learning to the real world</td>
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<tr>
<td>4. Making and interpreting representations</td>
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<td>5. Manipulating raw data</td>
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<td>6. Synthesizing and critiquing arguments</td>
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<td>7. Formative assessment</td>
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<td>8. Metacognitive reflection about data literacy</td>
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<td></td>
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<tr>
<td>----------------------------------------------</td>
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<tr>
<td><strong>Exploring Variability</strong></td>
</tr>
<tr>
<td>Consider and discuss sources of variability</td>
</tr>
<tr>
<td>Base confidence in claims on variability</td>
</tr>
<tr>
<td><strong>Math/Stats Practices</strong></td>
</tr>
<tr>
<td>Process raw data (sums, averages, indices)</td>
</tr>
<tr>
<td>Use statistics to describe a relationship</td>
</tr>
<tr>
<td><strong>Metacognition Practices</strong></td>
</tr>
<tr>
<td>Reflect on data knowledge and skills</td>
</tr>
<tr>
<td><strong>Representations Practices</strong></td>
</tr>
<tr>
<td>Represent/analyze data w/ tables, graphs</td>
</tr>
<tr>
<td>Discuss limits of different representations</td>
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<tr>
<td><strong>Evidence Based Reasoning Practices</strong></td>
</tr>
<tr>
<td>Explain reasoning for a critique or claim</td>
</tr>
<tr>
<td>Use data from others to support a claim</td>
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<tr>
<td><strong>Inquiry Teaching Practices</strong></td>
</tr>
<tr>
<td>Answer open-ended questions</td>
</tr>
<tr>
<td>Design and conduct scientific investigation</td>
</tr>
</tbody>
</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>Synthesizing and critiquing arguments</td>
<td>34</td>
<td>82%</td>
</tr>
<tr>
<td>Making and interpreting representations</td>
<td>112</td>
<td>68%</td>
</tr>
<tr>
<td>Evidence and principle-based reasoning</td>
<td>172</td>
<td>60%</td>
</tr>
<tr>
<td>Explicit learning about variability</td>
<td>191</td>
<td>52%</td>
</tr>
<tr>
<td>Manipulating raw data</td>
<td>87</td>
<td>43%</td>
</tr>
<tr>
<td>Connecting their learning to the real world</td>
<td>169</td>
<td>43%</td>
</tr>
<tr>
<td>Formative assessment</td>
<td></td>
<td></td>
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<td>Metacognitive reflection re: data literacy</td>
<td></td>
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</tr>
</tbody>
</table>
Hydrofracking Module - Teachers' Reported Implementation of Practices Related to Variability

- 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

[Bar chart showing the comparison between total possible and implemented practices for each activity]
Teacher Described **Constraints to Implementation** (all data)

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

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

- **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**
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
  – 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
  – 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
Questions?
An Evidence- and Reasoning-Based Critique and Inquiry Framework
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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

Darter
Damselfly
Whirligig
Beetle
Cicada
Mayfly
Butterfly
Mosquito
Water Bug
Grasshopper
Cricket
Katydid
Stinkbug
Water Boatman
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

- Induced Error: Measurer
- Induced Error: Sampling
- Induced Error: Processing
- Real Error
- Anthropogenic

N = 310 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
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**

- **Total Possible**
- **Implemented**

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

- **Total Possible**
- **Implemented**