Cary Institute of Ecosystem Studies

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
- National Science Foundation, NSF Grant DRL-1020186
- Cary Institute Scientists
  - Dave Strayer
  - Stuart Findlay
  - Bill Schlesinger

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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

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.*

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Data Literacy Skills

National Research Council. 2012. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.*

Locally Relevant Socio-Ecological Issues

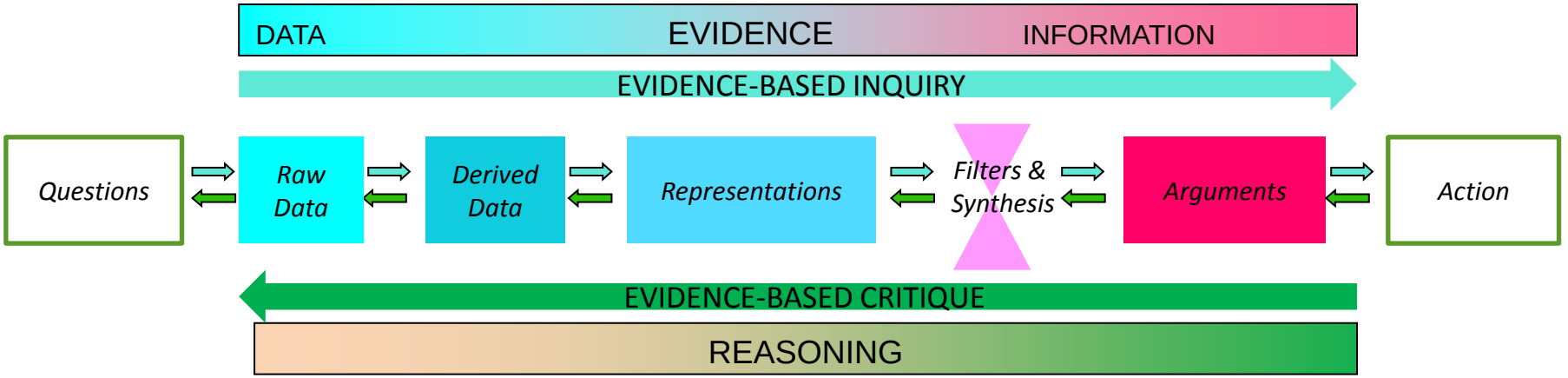
Hydro Fracking

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



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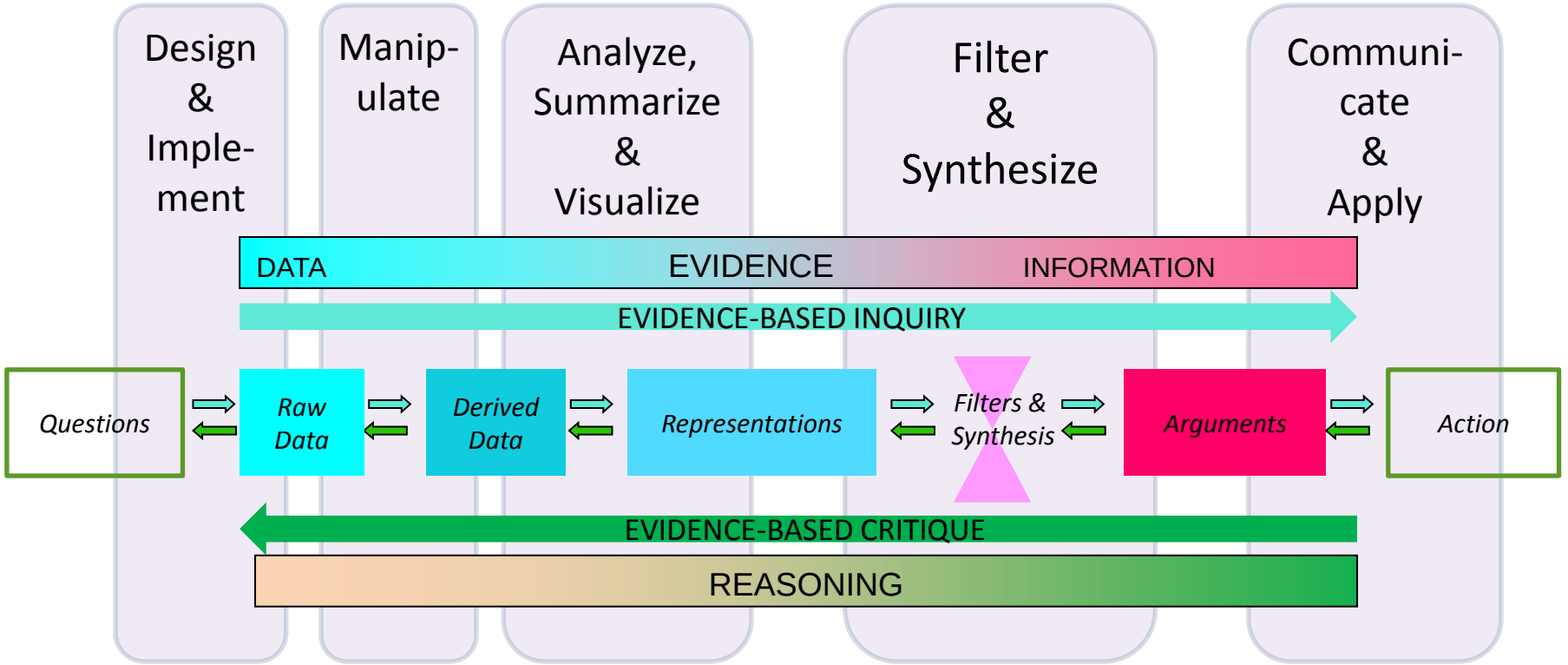


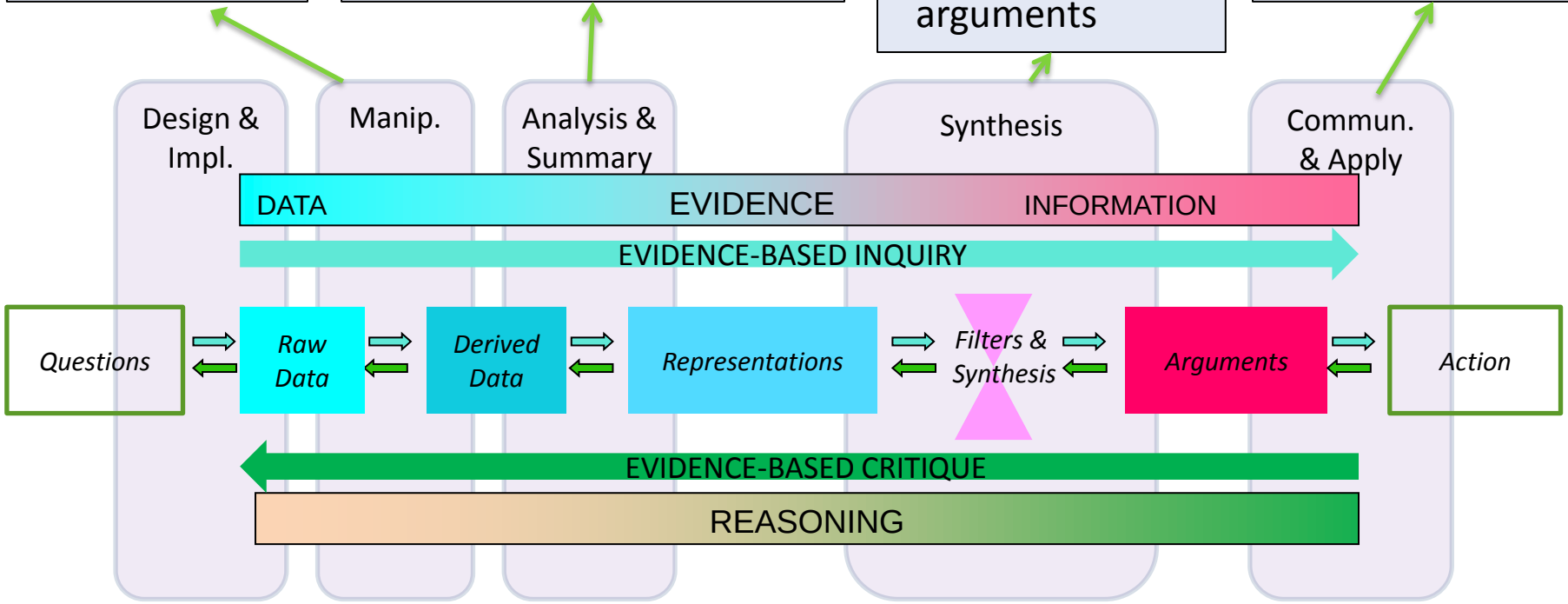
Progress Variables

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

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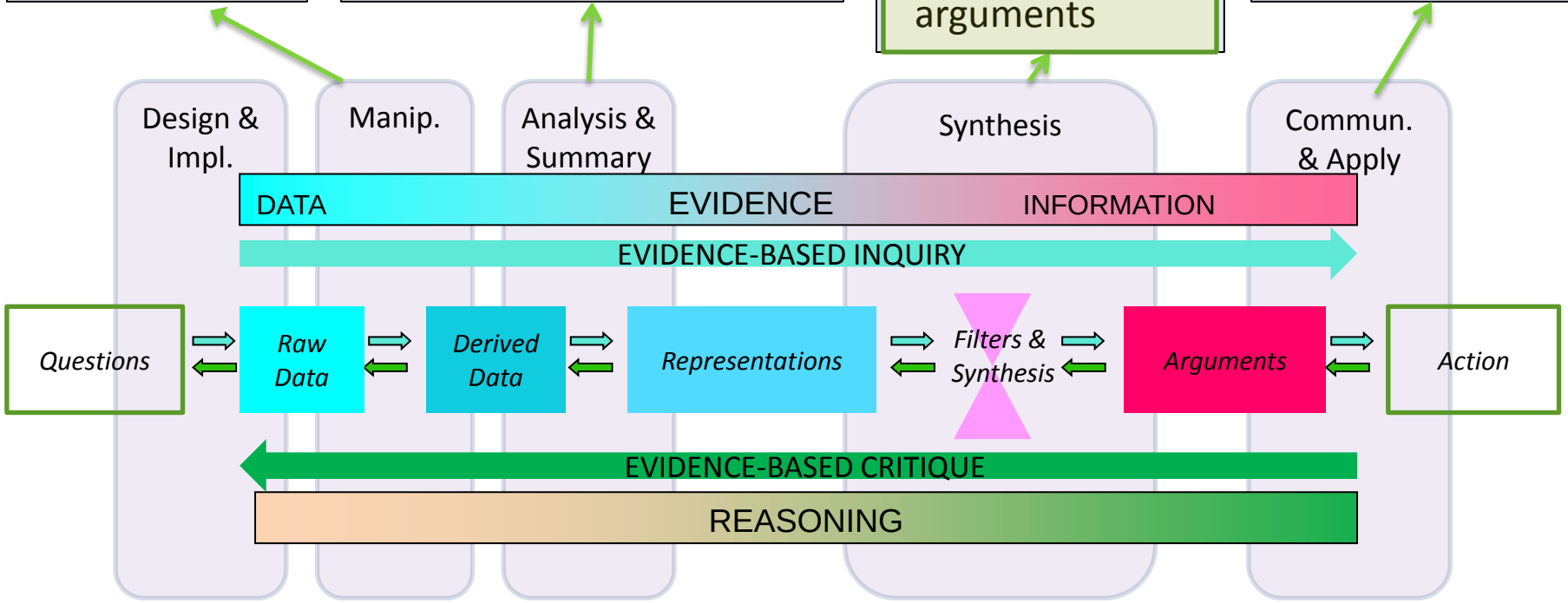
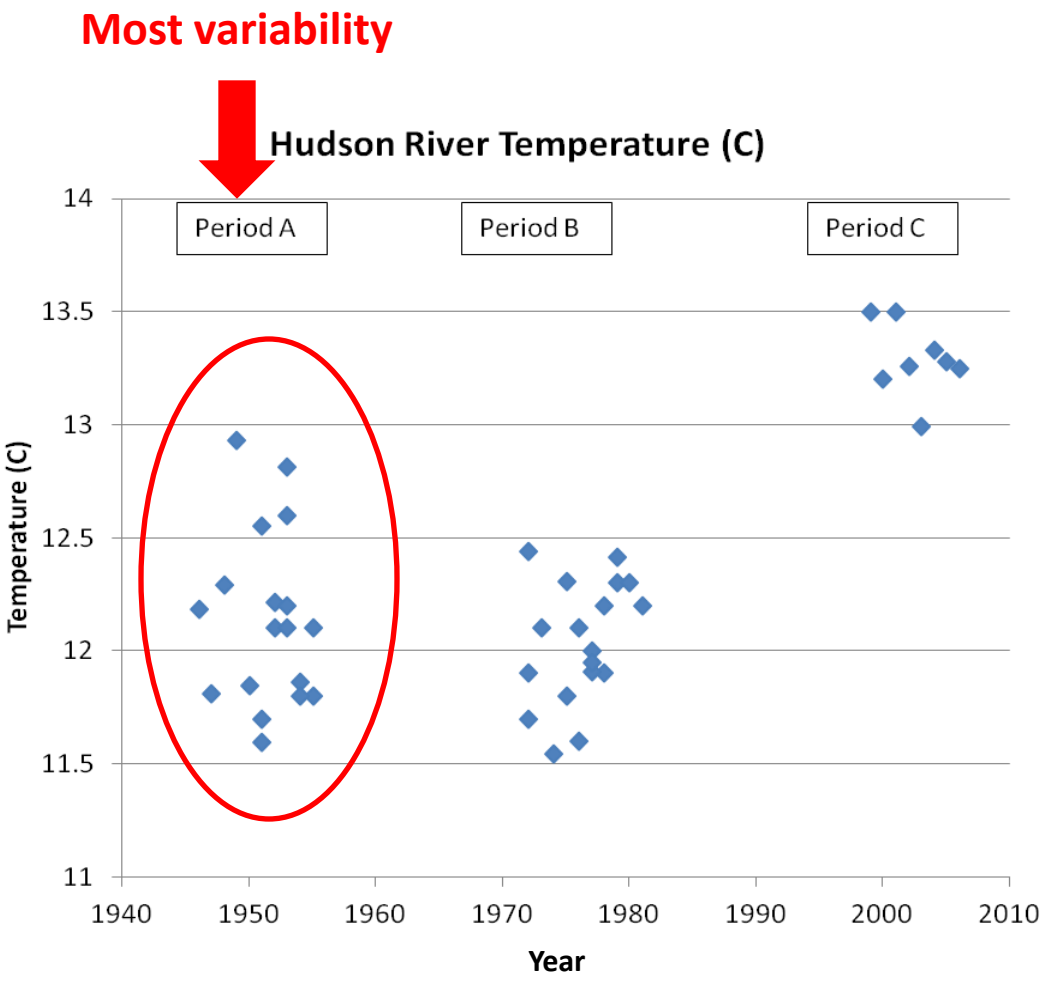


What do students understand about the concept of ***variability*** in data exploration?

- 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

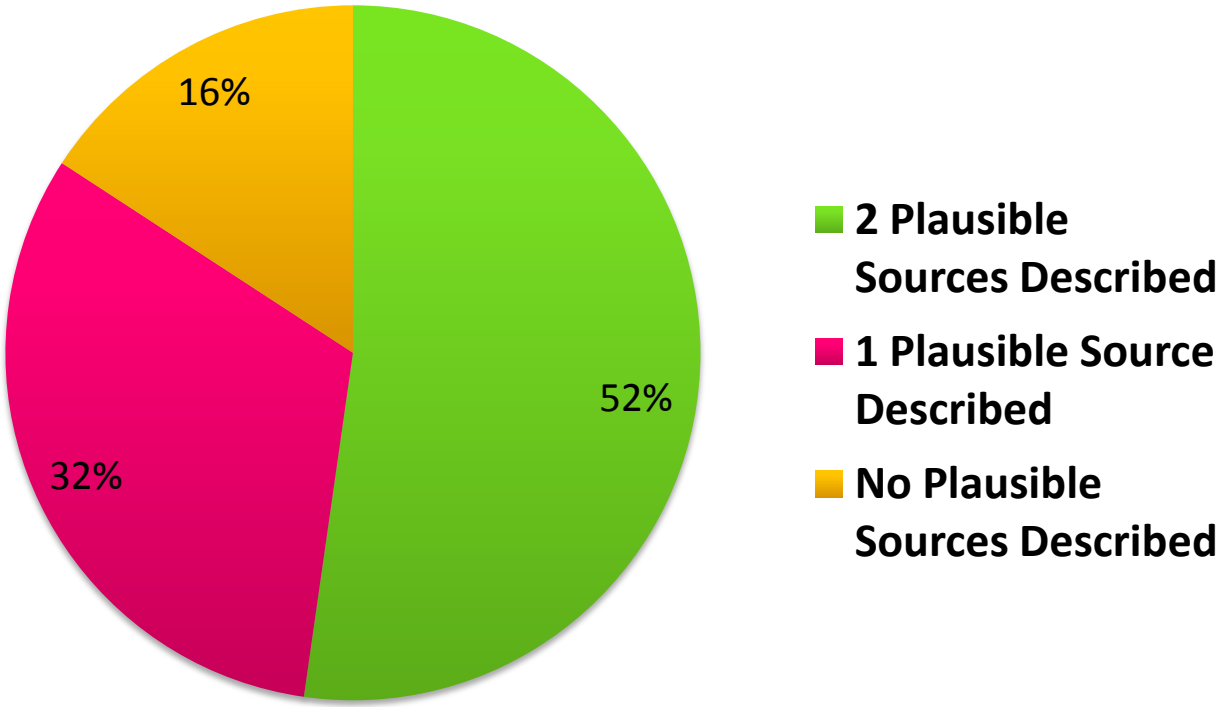
90% of students recognize variability

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)*



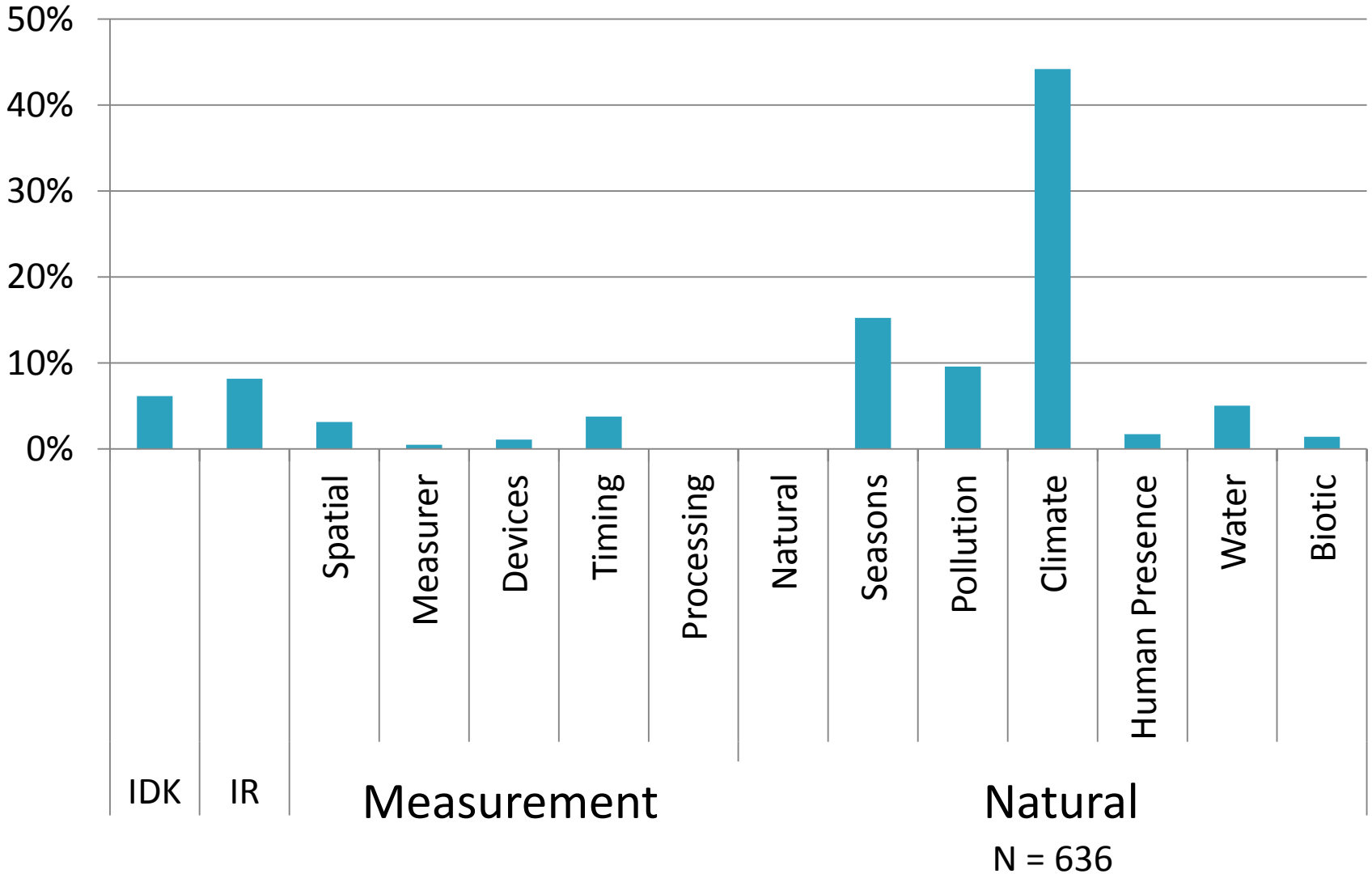
About 84% of students can list at least one plausible source of variability

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



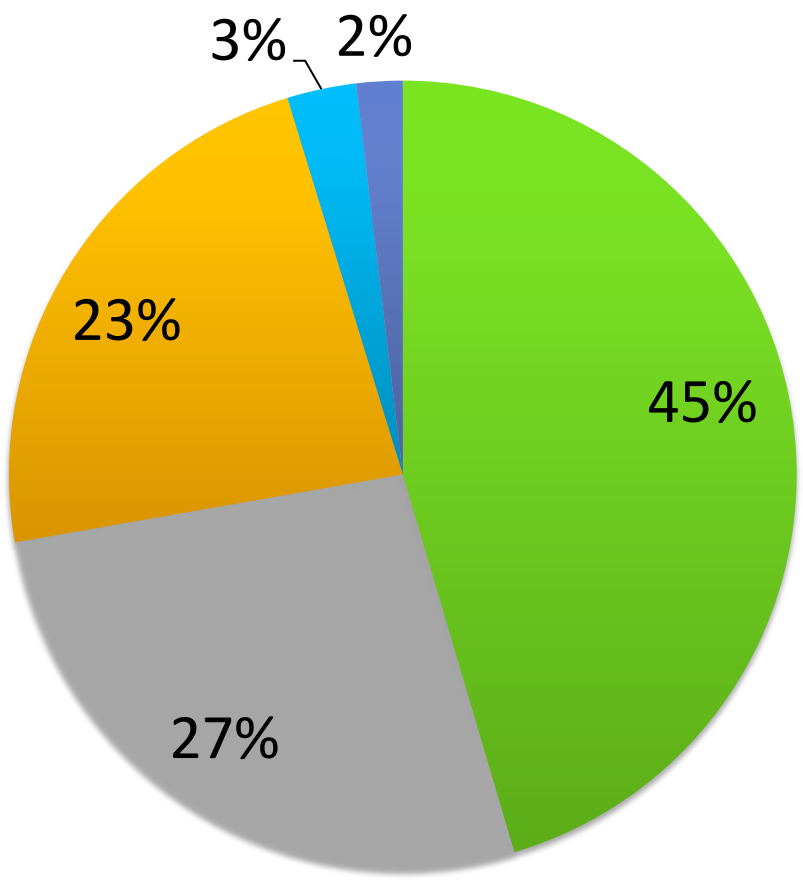
N = 310 Students

Students identify many sources of variability



Very few students describe variability in a set of data as providing insight into natural processes

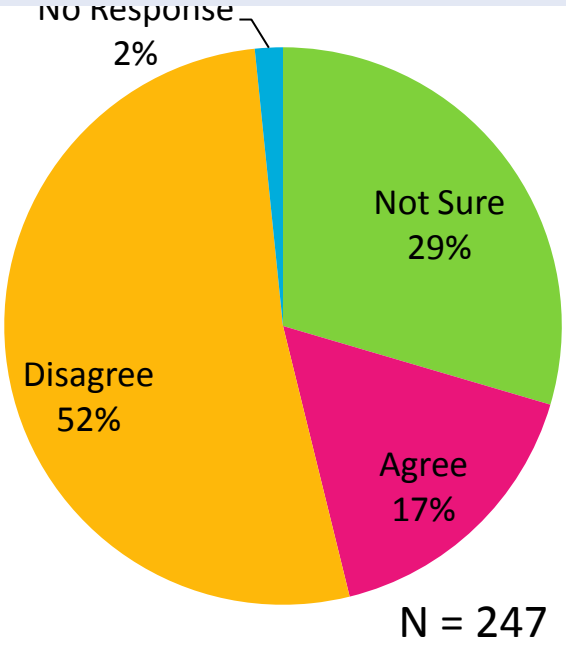
Why is it important to think about variability in a set of data?



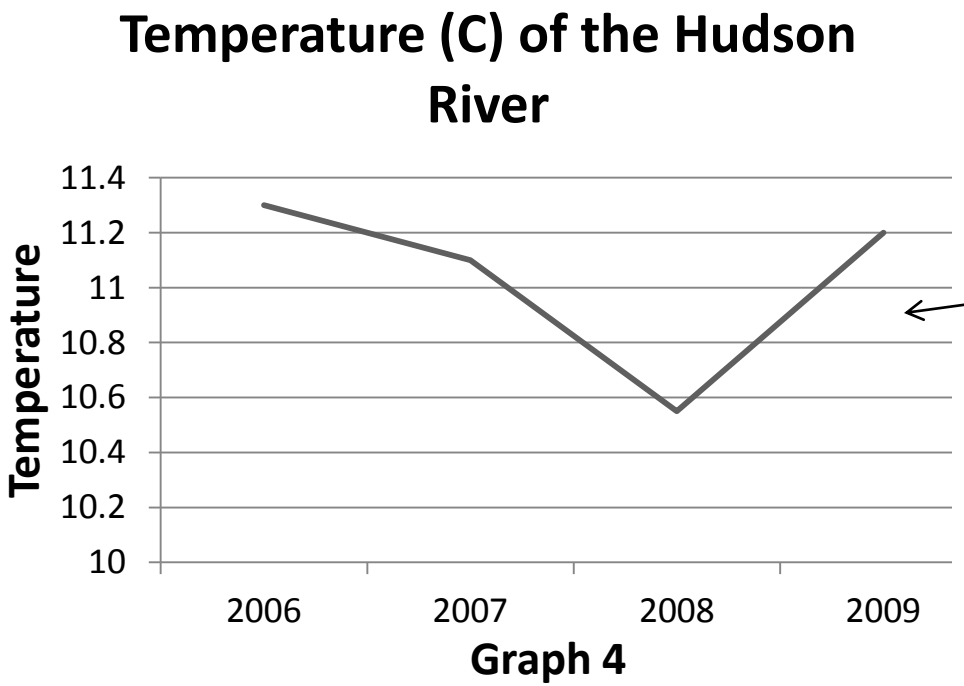
N = 310 students

Evaluating Claims Based on Evidence

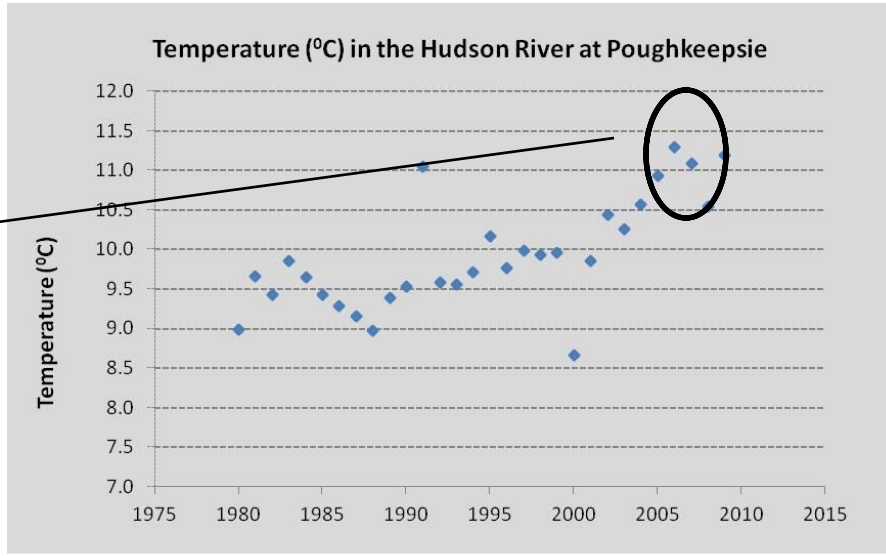
A local factory owner is trying to get a permit to discharge warm water into the Hudson River. He uses Graph 4 to support his claim that the water temperature of the river is variable, and thus it doesn't matter if he adds a bit more warm water to the river. Do you agree or disagree with his claim? Explain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



N = 247

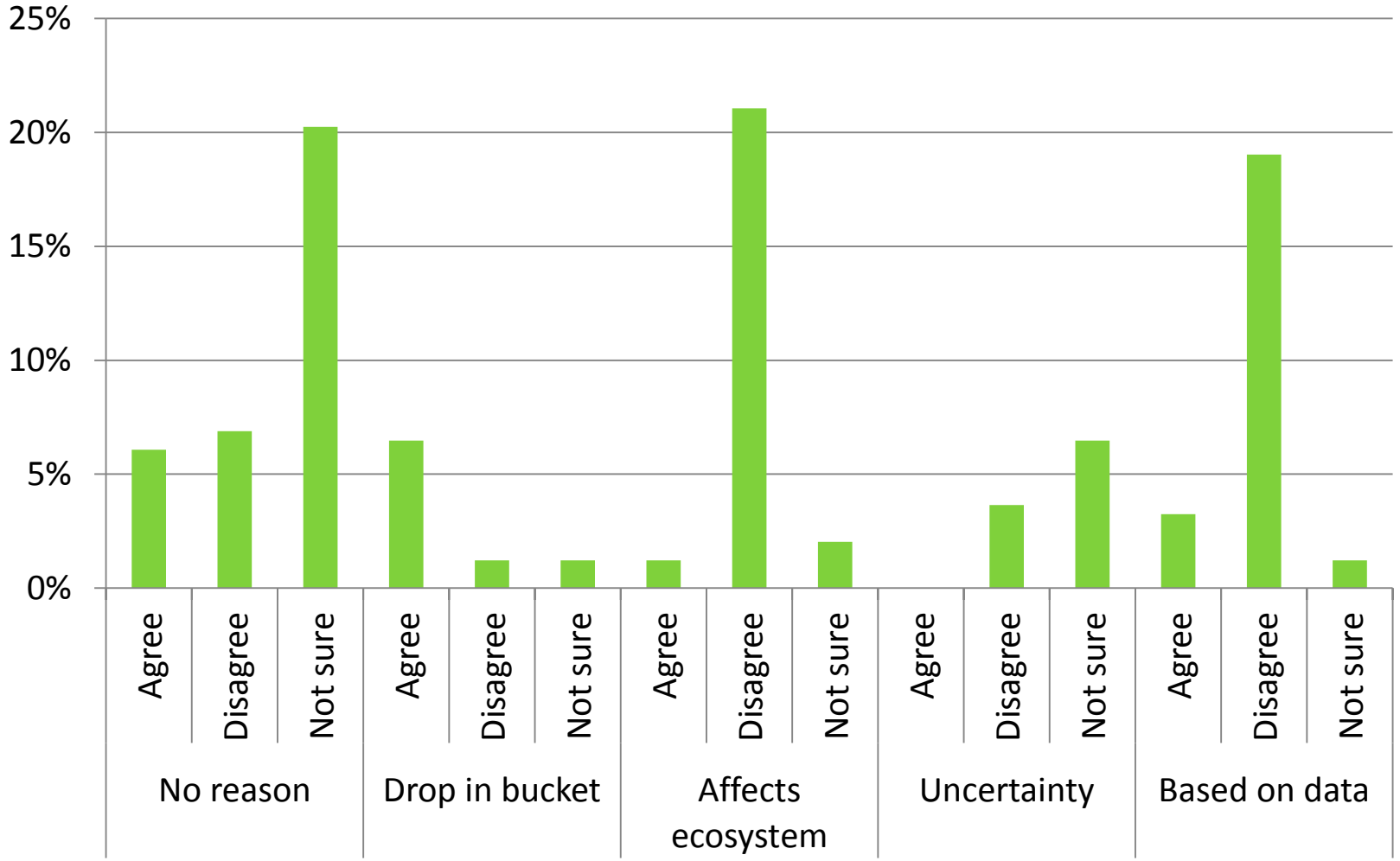


Graph 4

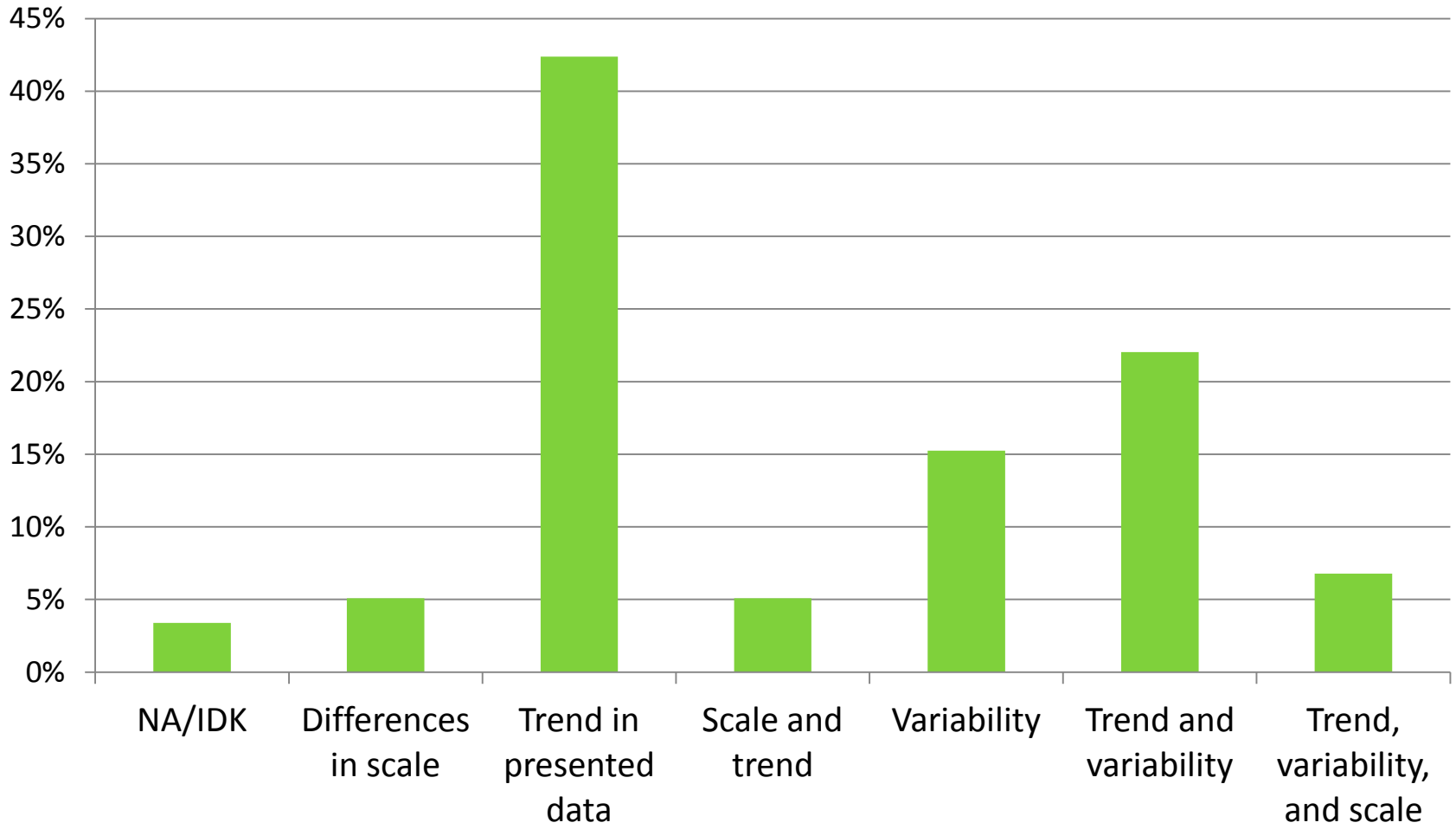


Graph 3

Reasons: Why did students agree or disagree?

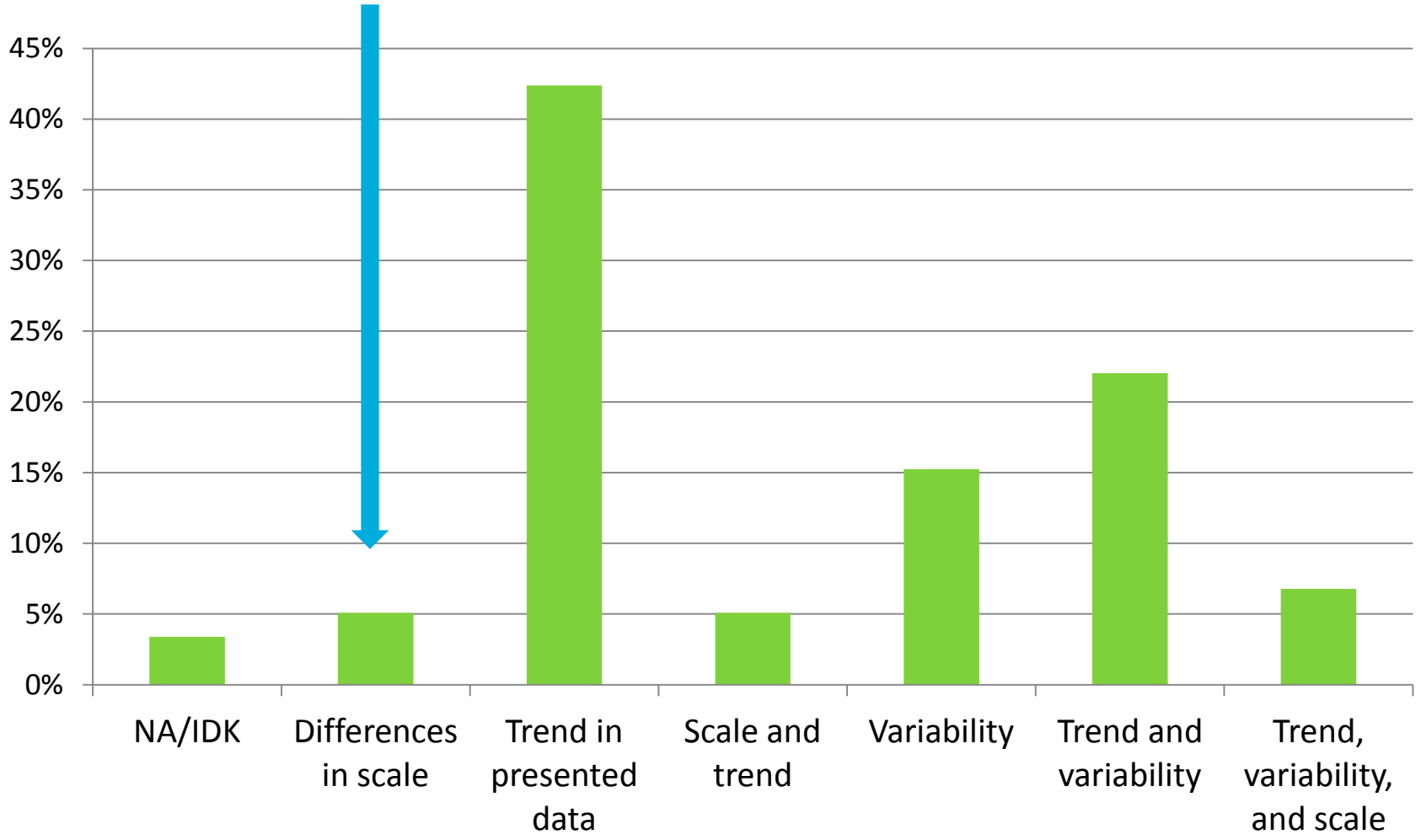


Attention to data: what did students focus on when they talked about data?



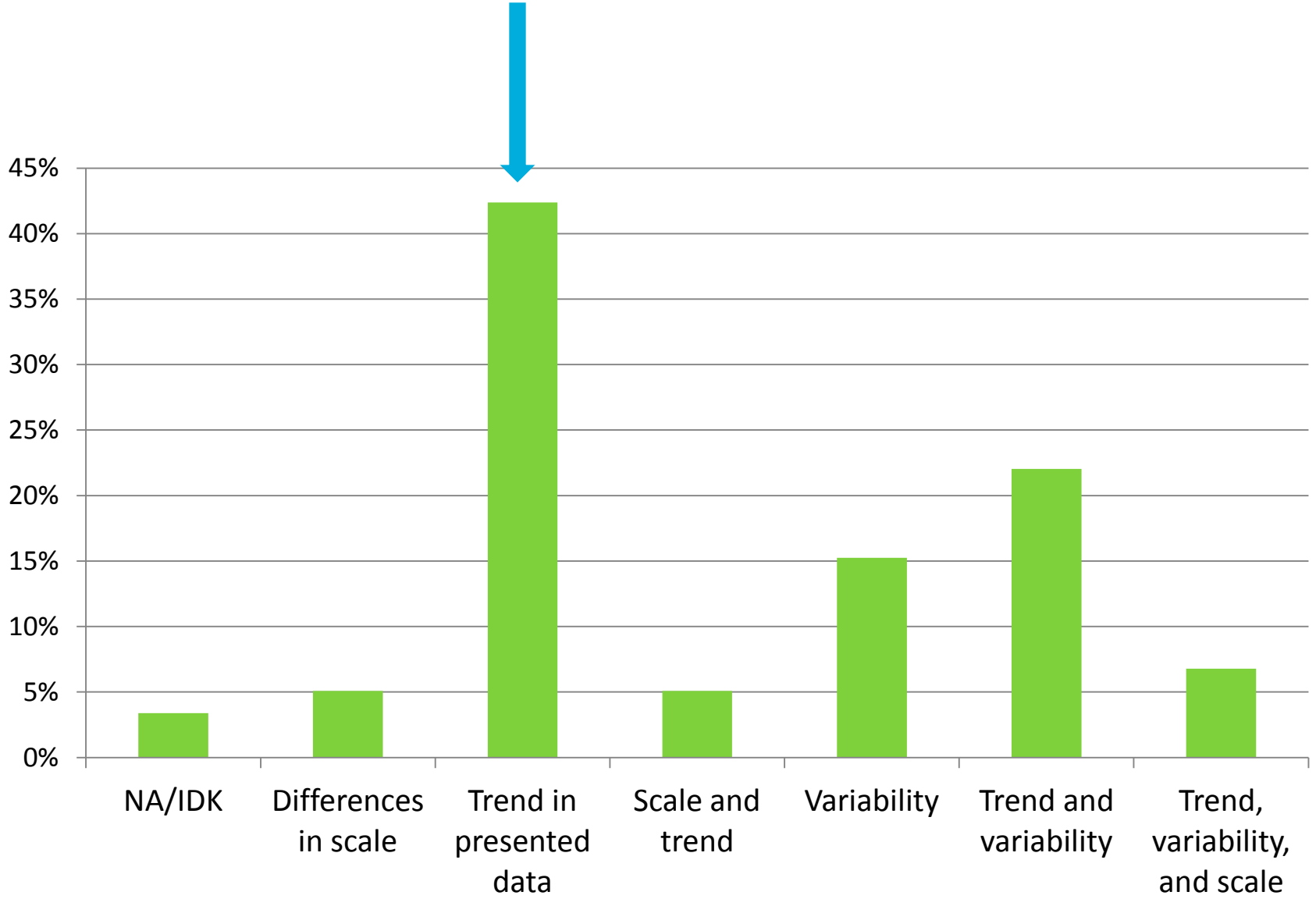
N = 59 (students who mentioned data in their answer)

“He used the graph that didnt show the temp. was rising so that he would get permission when it would obviously matter if he used another graph.”



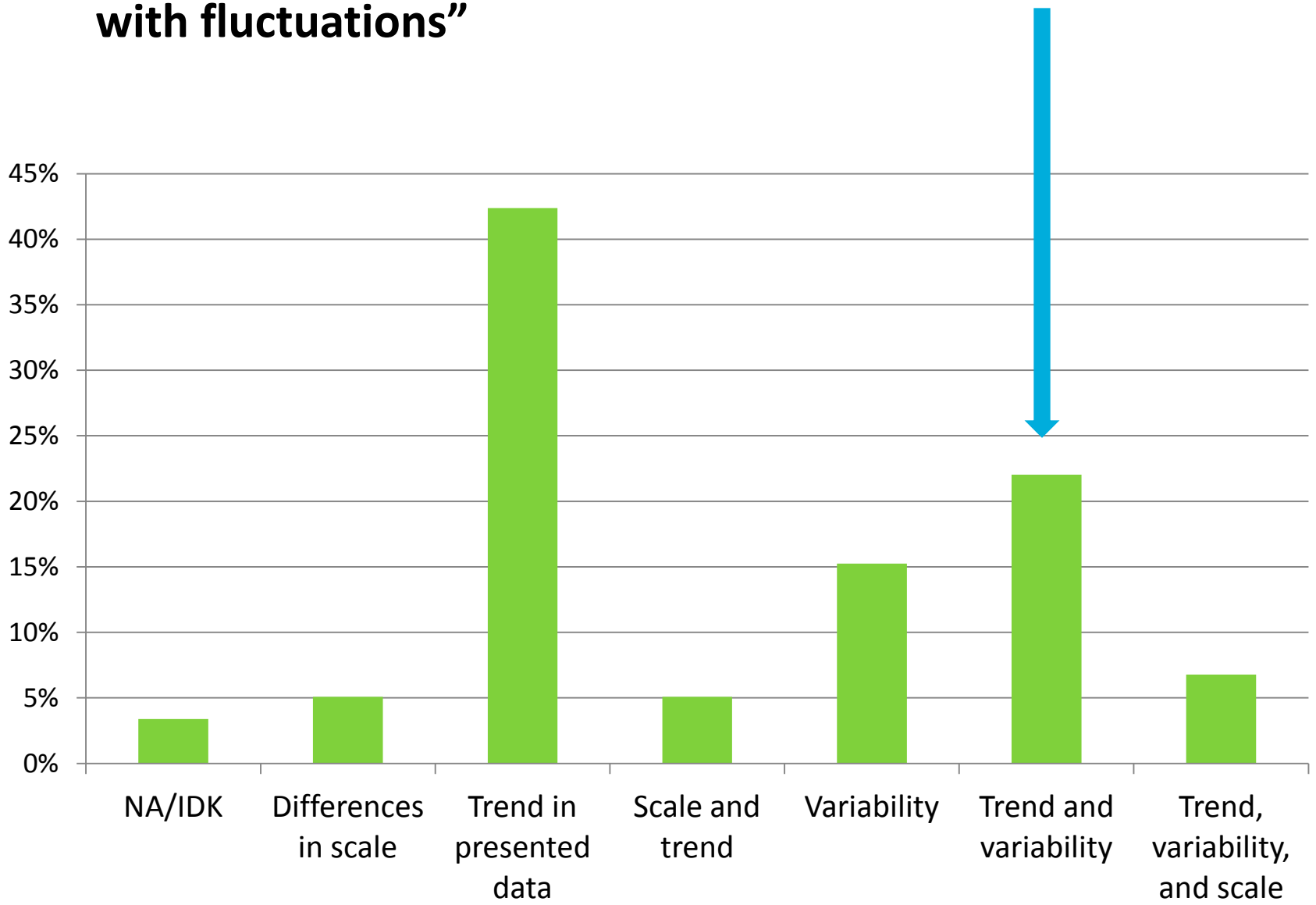
N = 59 (students who mentioned data in their answer)

“The water temperature already was increasing”



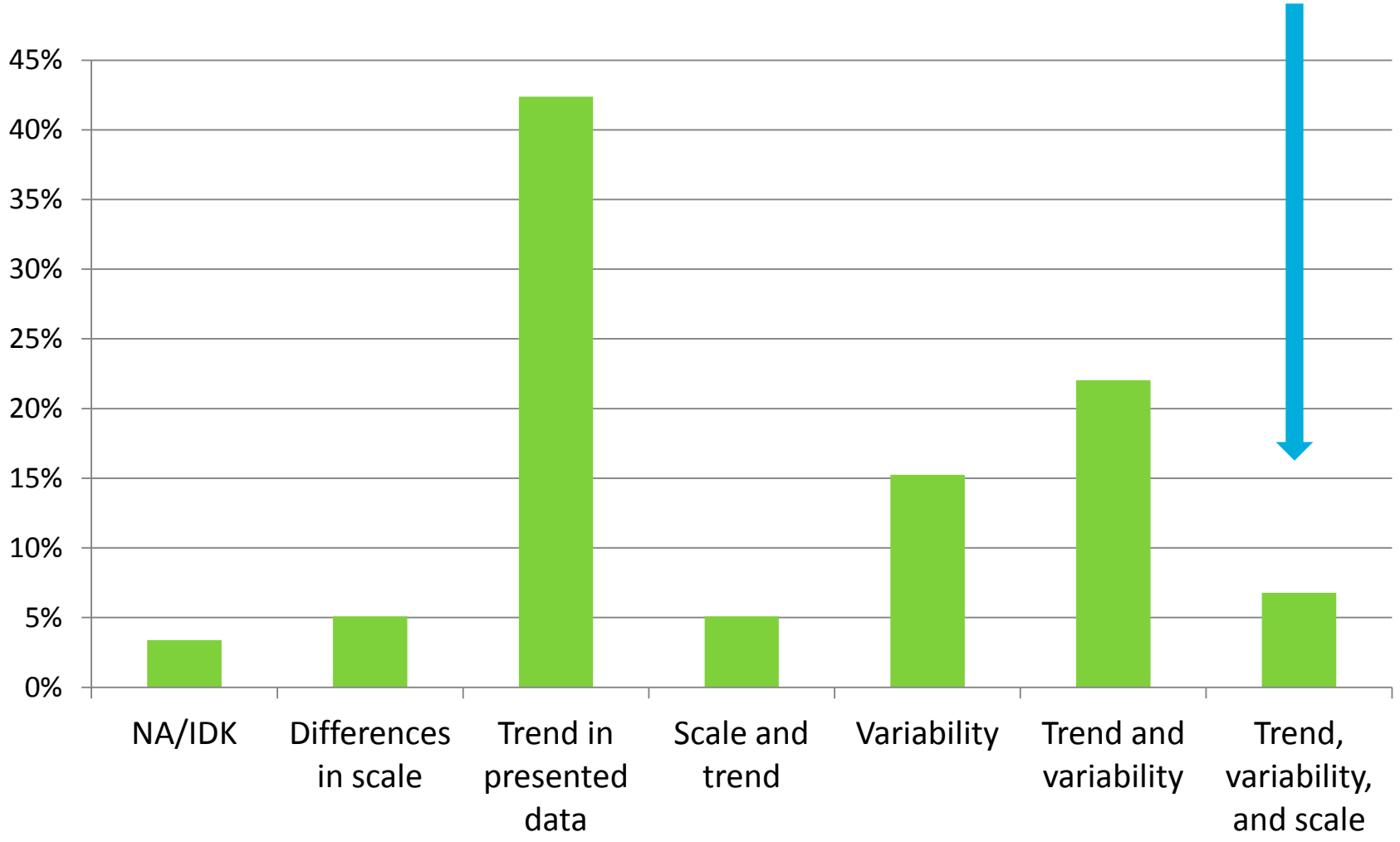
N = 59 (students who mentioned data in their answer)

“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."



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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 dat
  - 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**

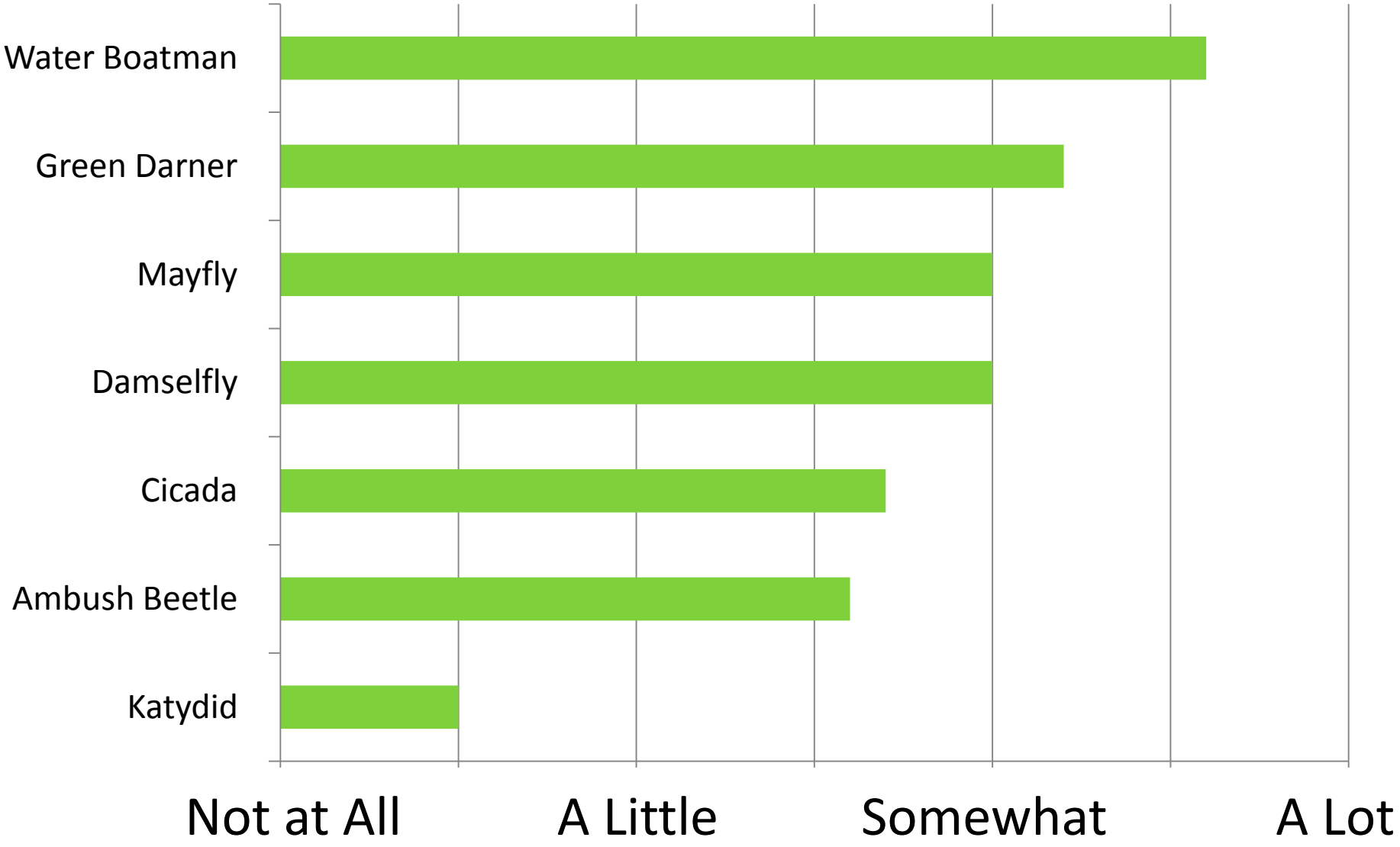
Key Data Literacy Practices

Students are engaged in …
1. Explicit learning about variability
2. Evidence and principle-based reasoning
3. Connecting their learning to the real world
4. Making and interpreting representations
5. Manipulating raw data
6. Synthesizing and critiquing arguments
7. Formative assessment
8. Metacognitive reflection about data literacy

Self-Reported Use of Practices (pre-program)

	Never	1-2/ yr	1/ 2mths	1-2/ mth	1-2/ wk	Every day	Mean
Exploring Variability							
Consider and discuss sources of variability	0	1	2	8	2	0	2.85
Base confidence in claims on variability	4	2	4	3	1	0	1.64
Math/Stats Practices							
Process raw data (sums, averages, indices)	0	1	6	6	1	0	2.50
Use statistics to describe a relationship	4	3	5	1	1	0	1.43
Metacognition Practices							
Reflect on data knowledge and skills	2	5	2	3	1	0	1.69
Representations Practices							
Represent/analyze data w/ tables, graphs	0	1	3	3	7	0	3.14
Discuss limits of different representations	1	4	4	4	1	0	2.00
Evidence Based Reasoning Practices							
Explain reasoning for a critique or claim	0	1	2	6	5	0	3.07
Use data from others to support a claim	0	2	2	7	3	0	2.79
Inquiry Teaching Practices							
Answer open-ended questions	0	0	1	1	8	4	4.07
Design and conduct scientific investigation	0	1	6	3	4	0	2.71

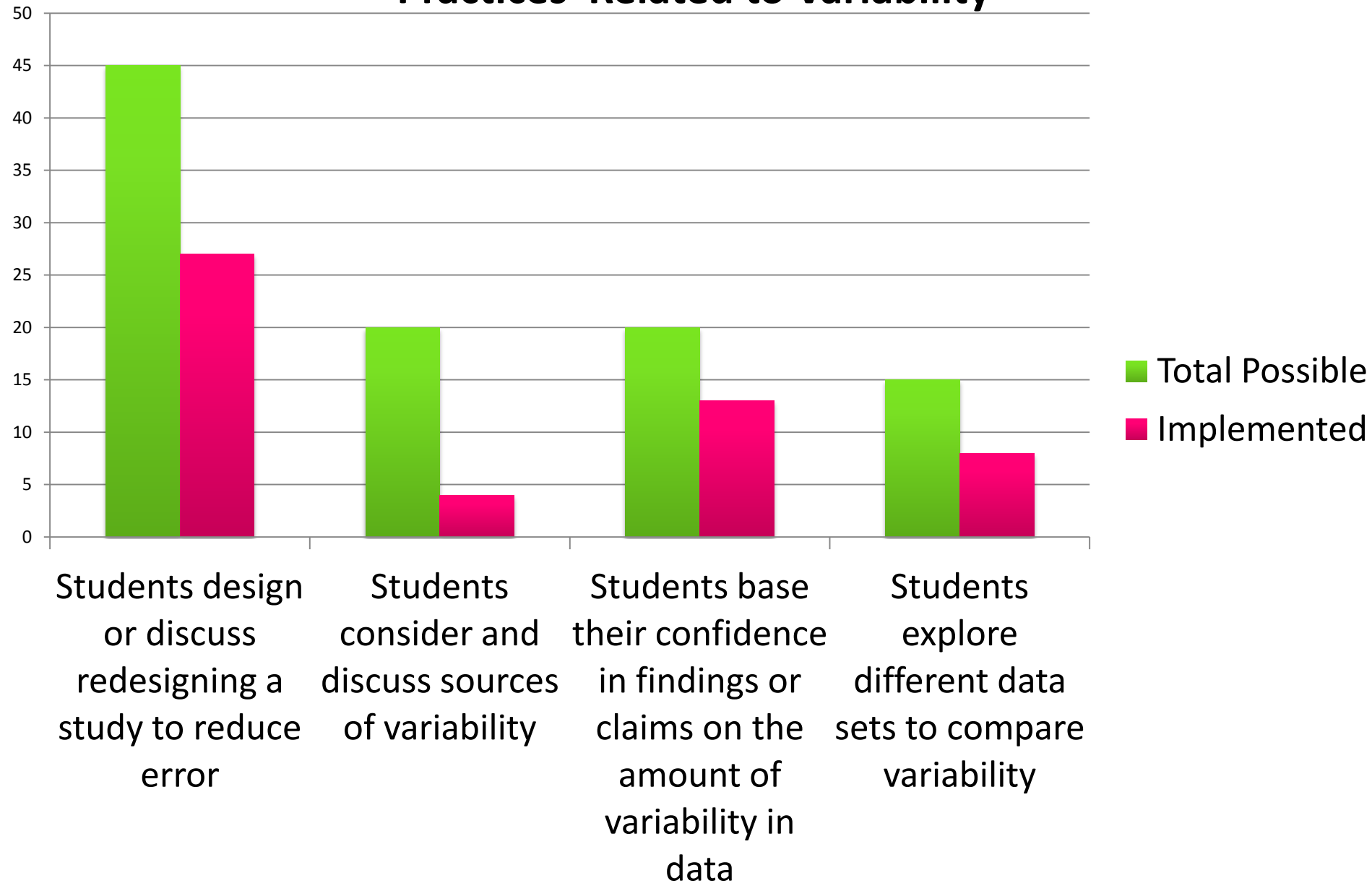
Mean Self-Reported Use of Key Data Literacy Practices - Own Module



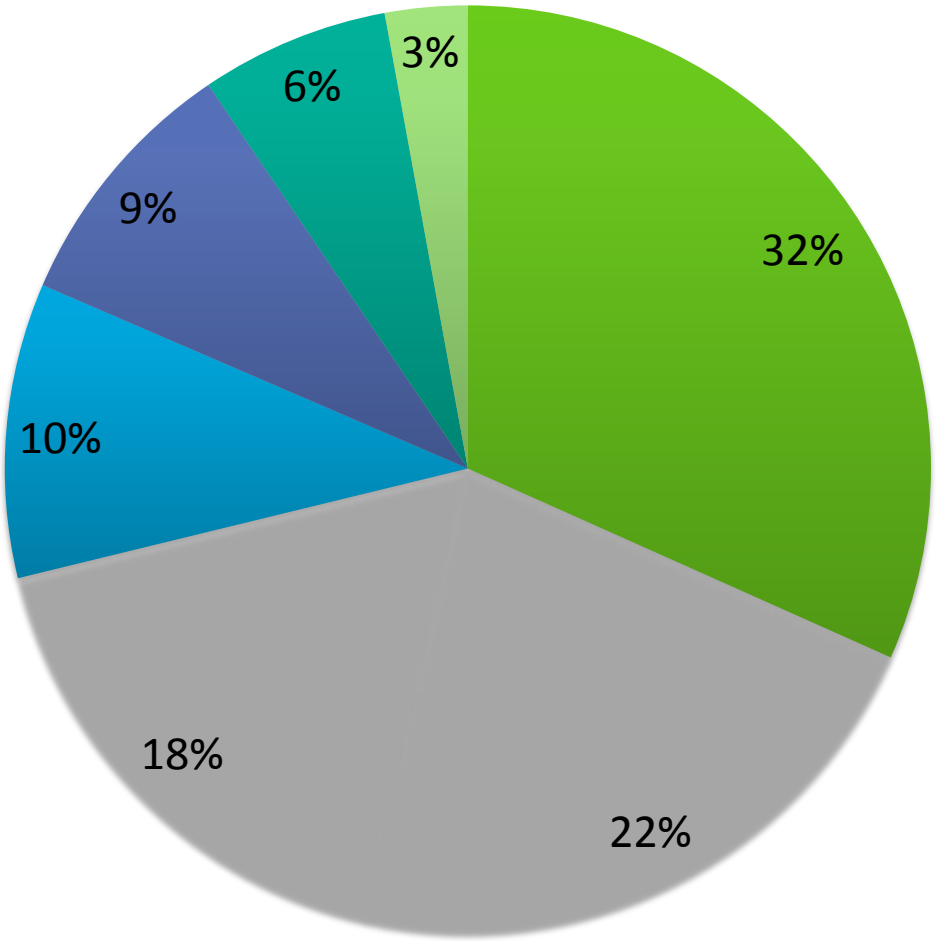
Overall Implementation of the Practices (DEEP Modules)

Students are engaged in …	# possible	% done
Synthesizing and critiquing arguments	34	82%
Making and interpreting representations	112	68%
Evidence and principle-based reasoning	172	60%
Explicit learning about variability	191	52%
Manipulating raw data	87	43%
Connecting their learning to the real world	169	43%
Formative assessment		
Metacognitive reflection re: data literacy		

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



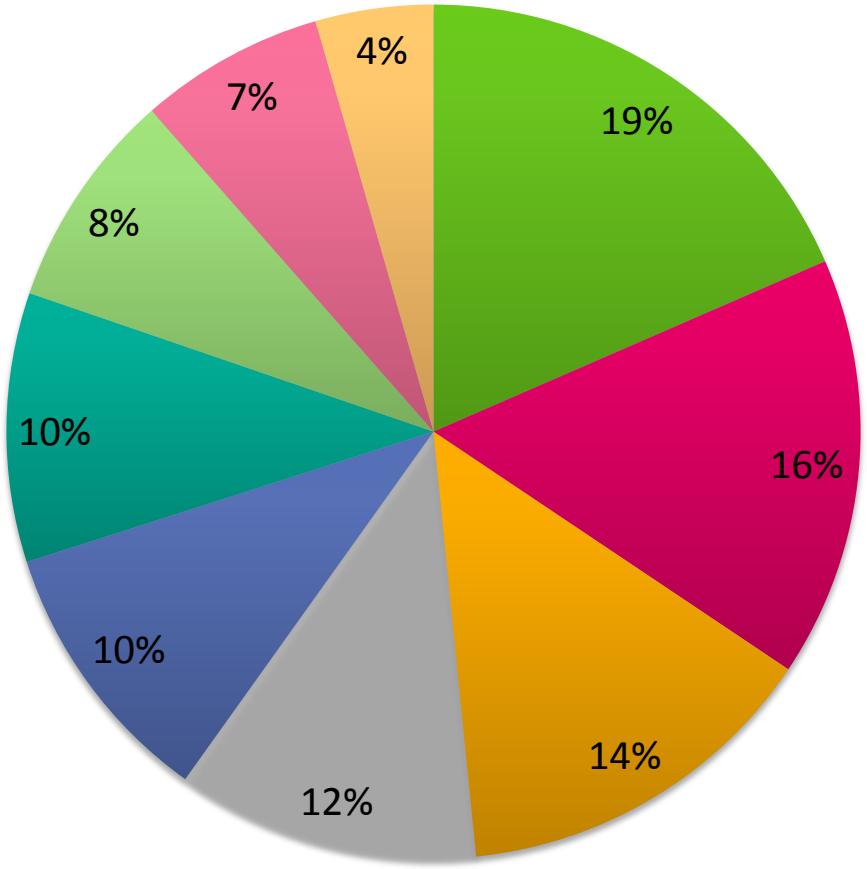
Teacher Described **Constraints** to Implementation (all data)



- Time
- Student KSAs
- DE Skills
- Curriculum integration
- Access to Data
- Access to resources
- Content knowledge

of 243 total utterances

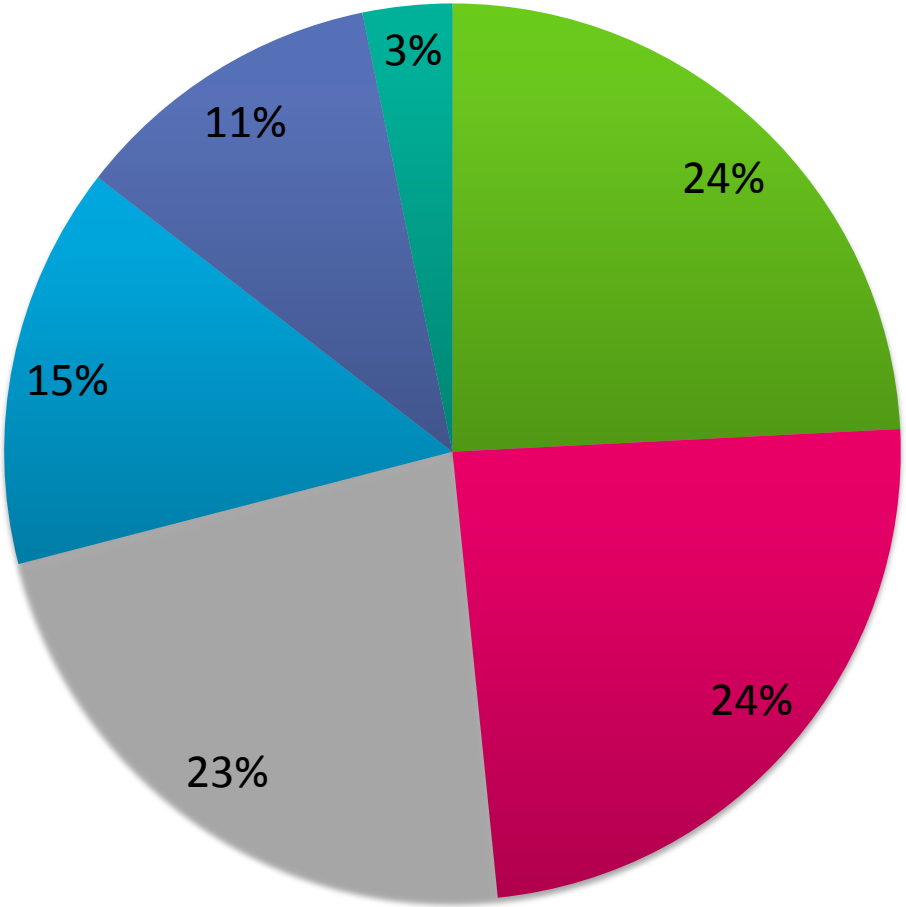
Teacher Described **Supports** to Implementation (all data)



of 157 total utterances

- **Student KSAs - data collection**
- **Participation in a PLC**
- **Working with Cary scientists**
- **Engagement in PD activities**
- **PD provider support**
- **Curriculum materials**
- **Teacher learning**
- **Involvement in module development**
- **Timing of the PD workshops**

Teacher Described **Motivations** to Teach DE (all data)



- 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

of 62 total utterances

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?

Cary Institute of Ecosystem Studies

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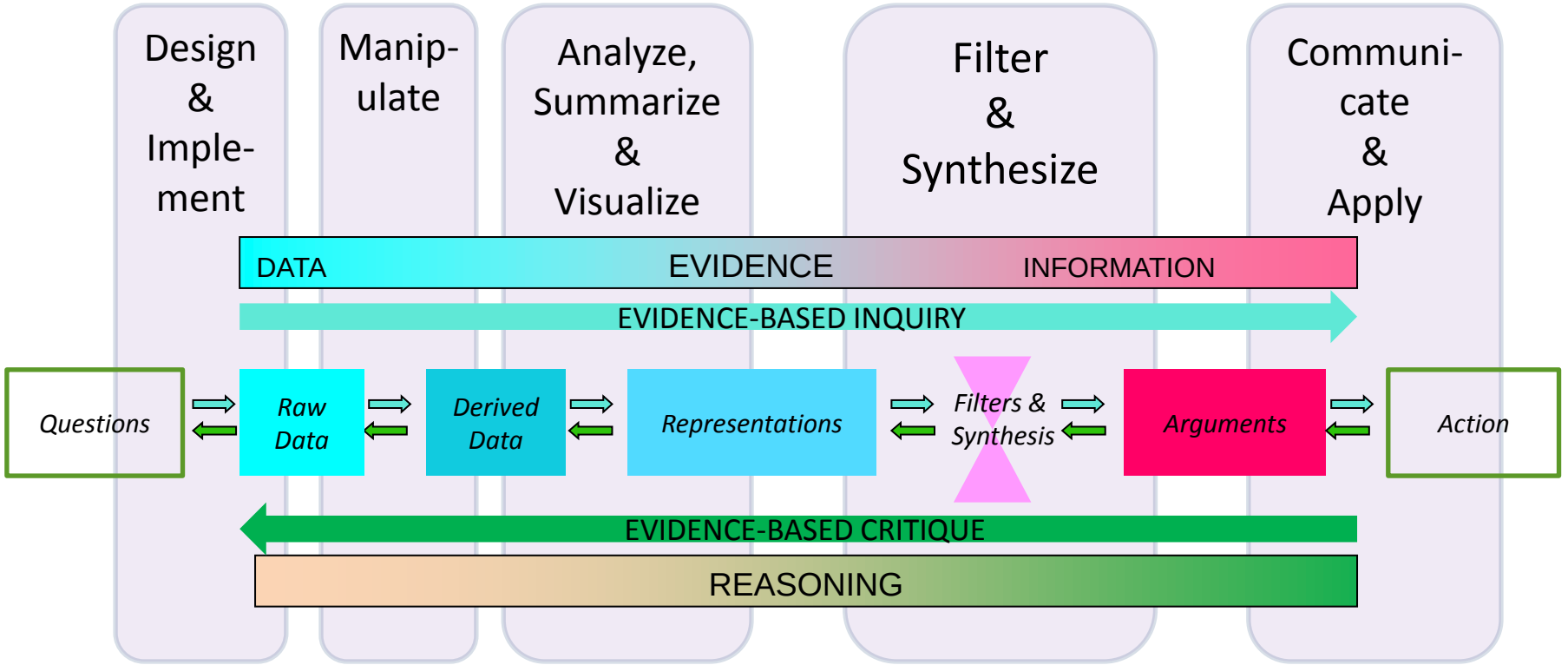
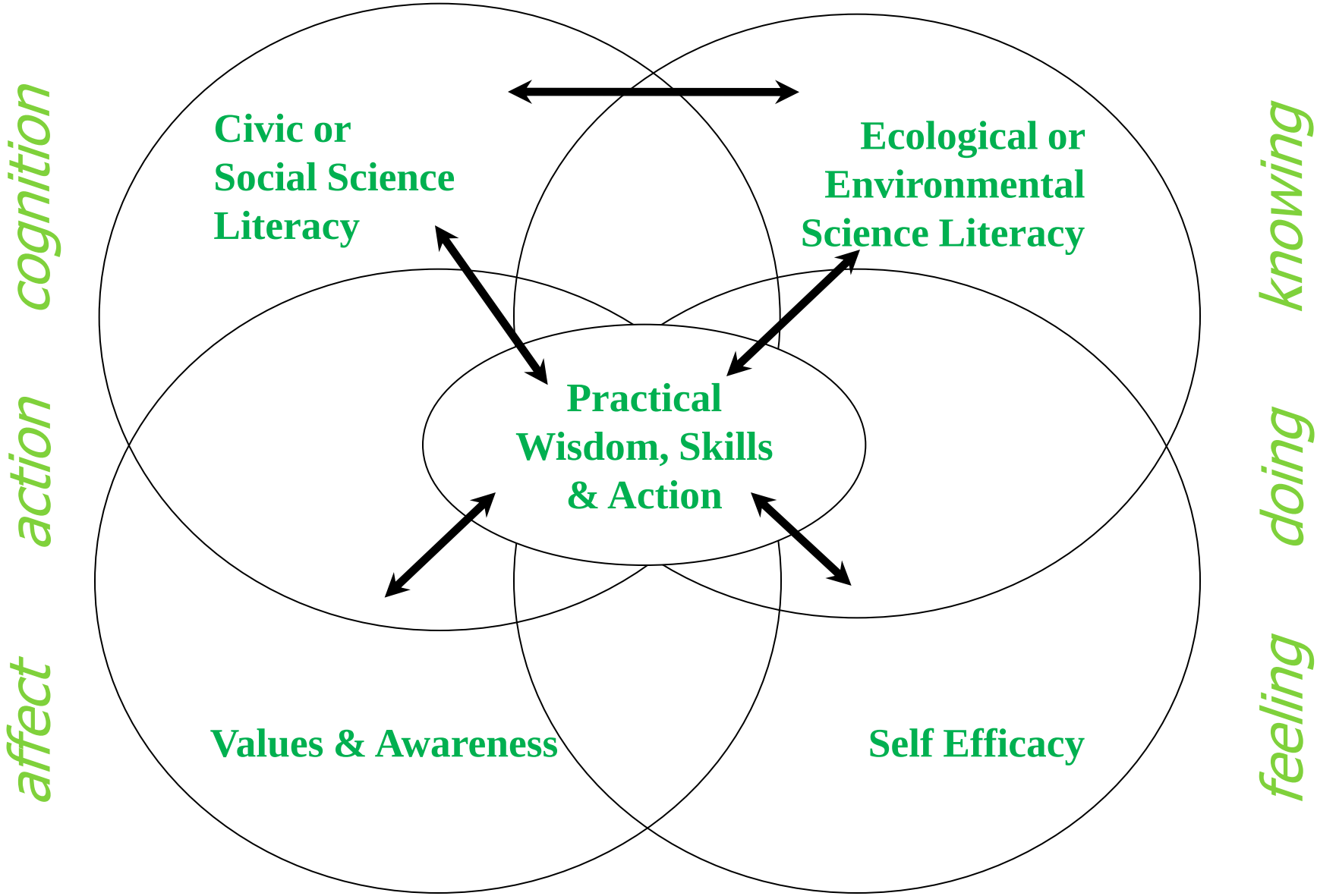
An Evidence- and Reasoning-Based Critique and Inquiry Framework



Environmental Citizenship



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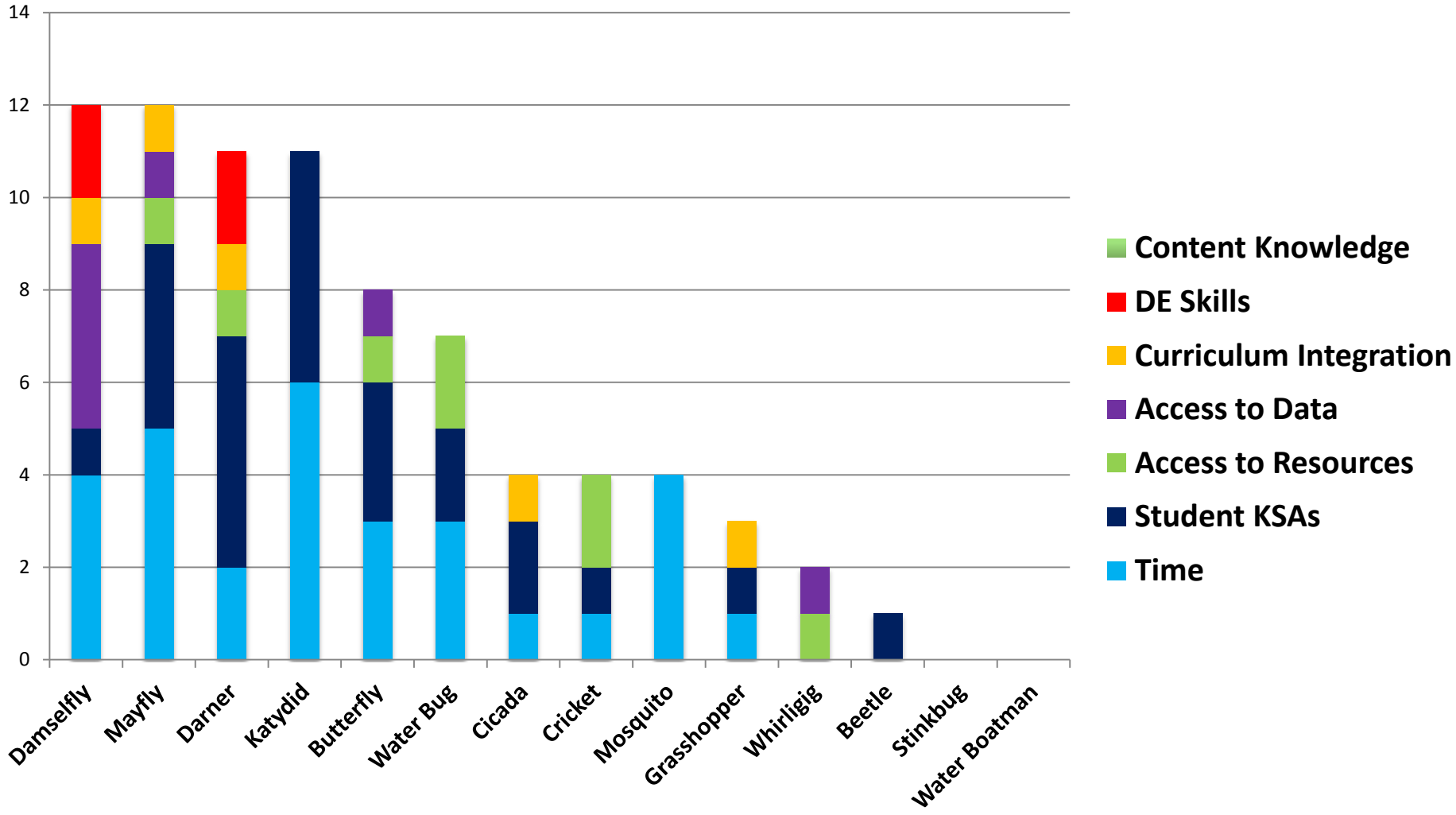
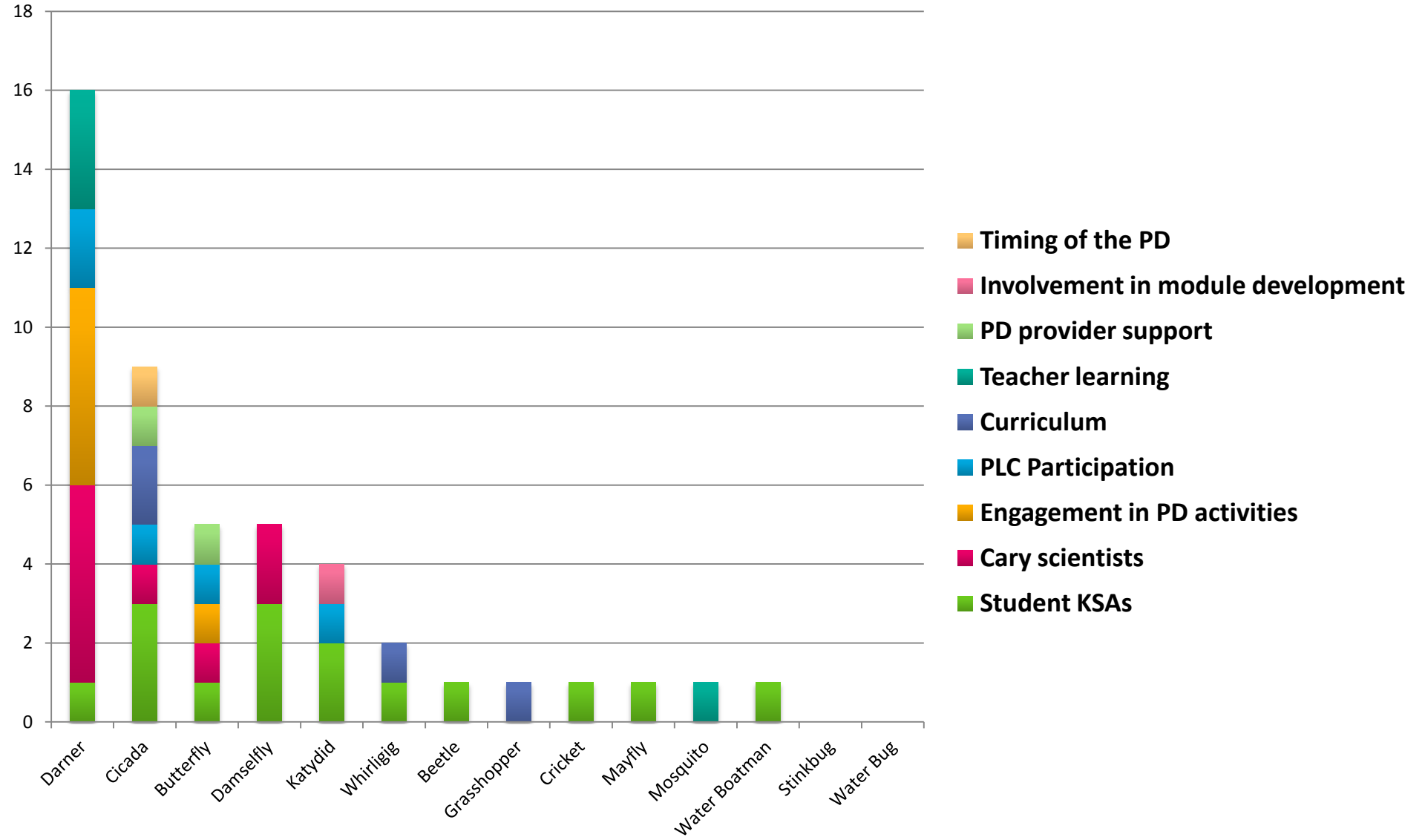
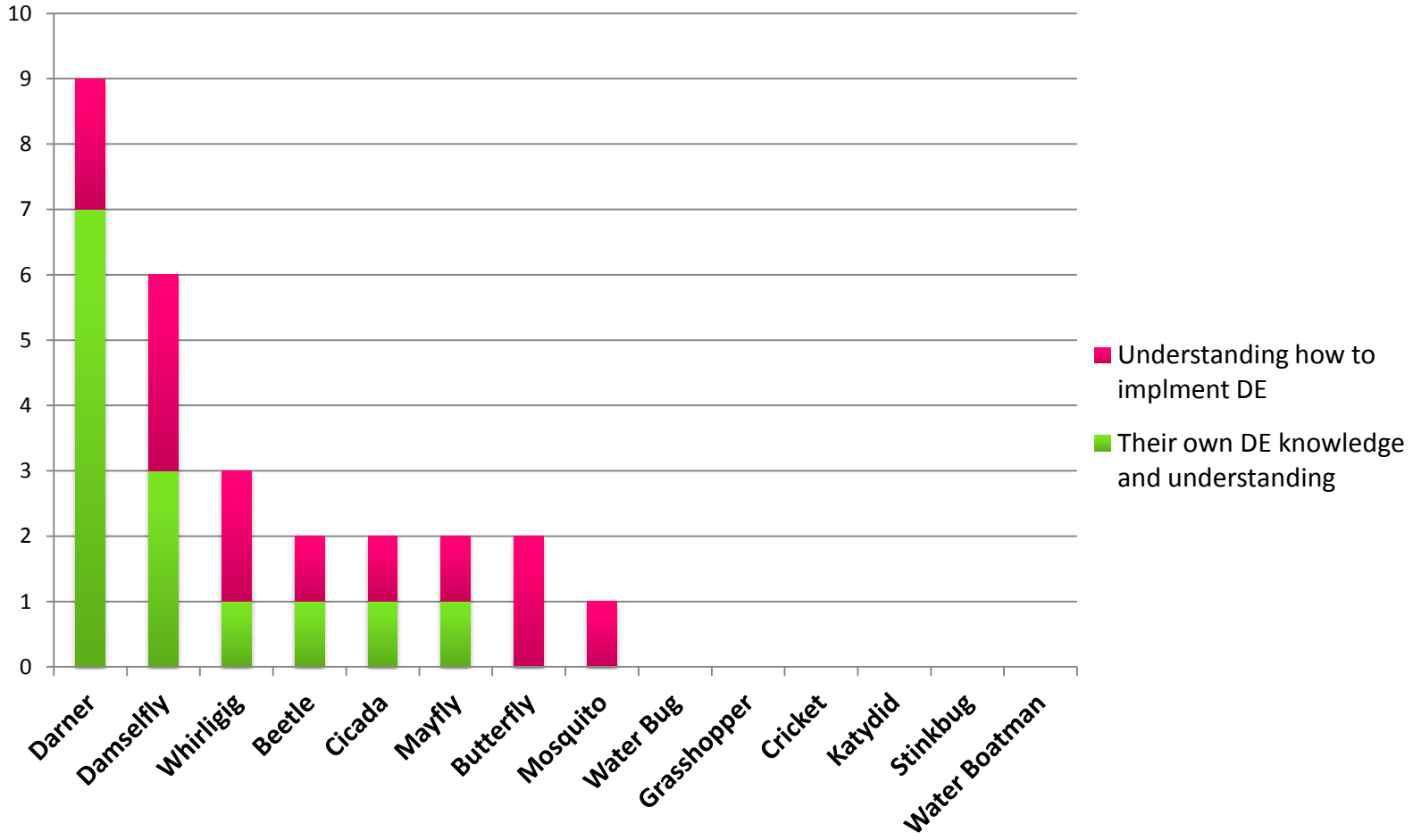


Teacher Described **Supports** to Implementation by Individual Teacher

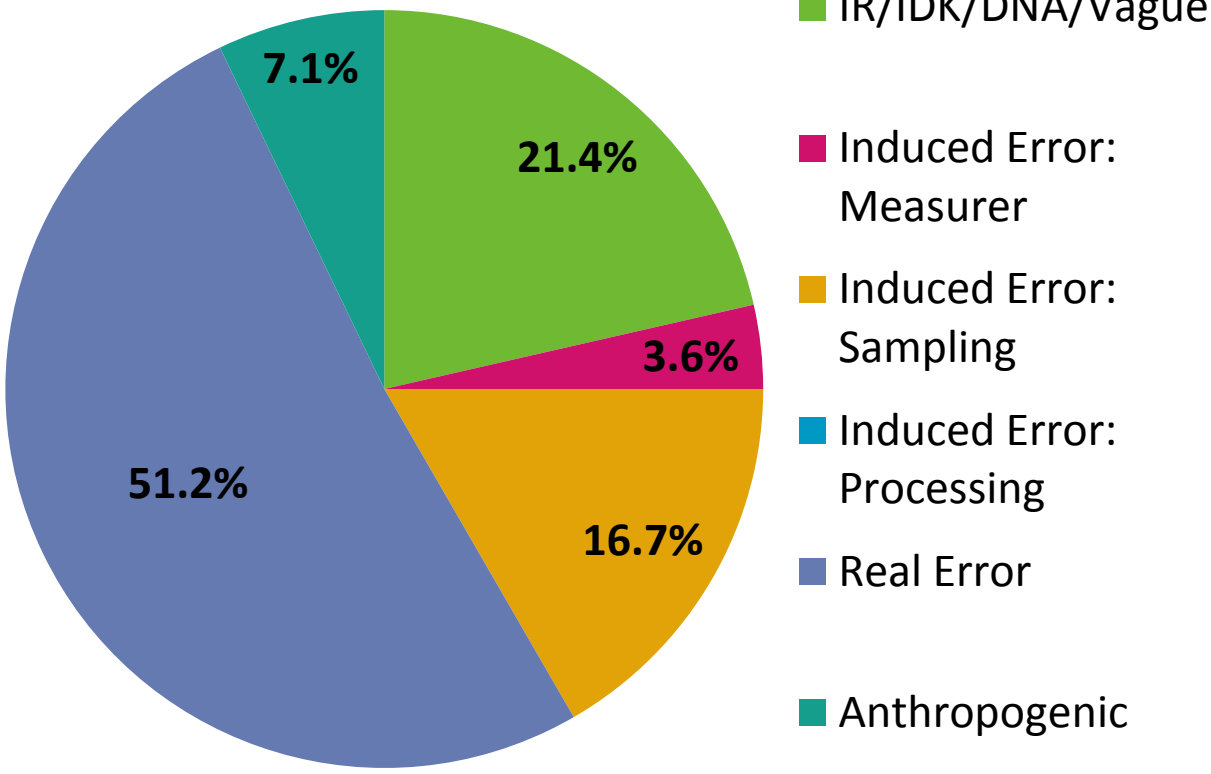


Self-efficacy by Teacher (n=27)



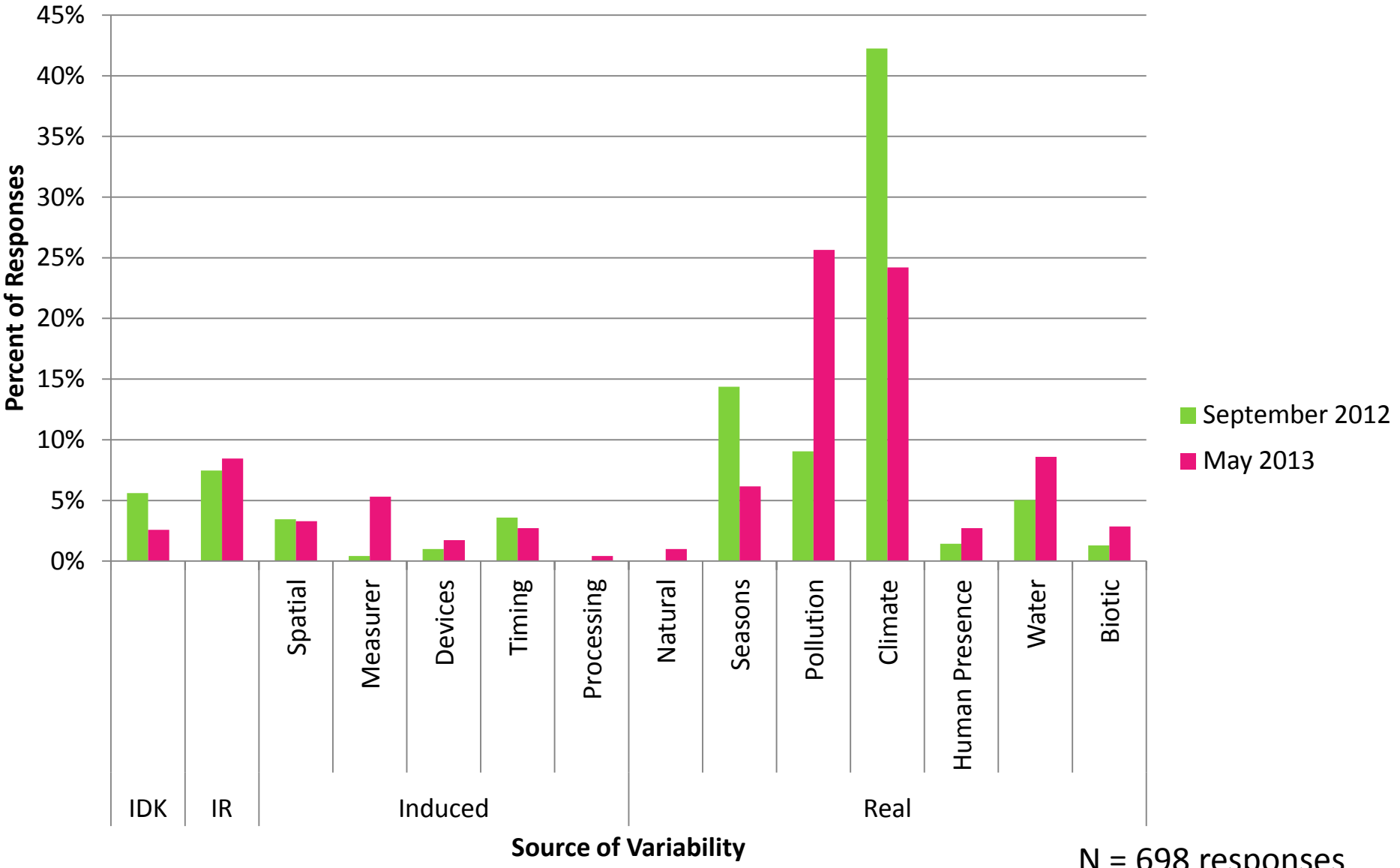
Student-Listed Sources of Variability

- **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



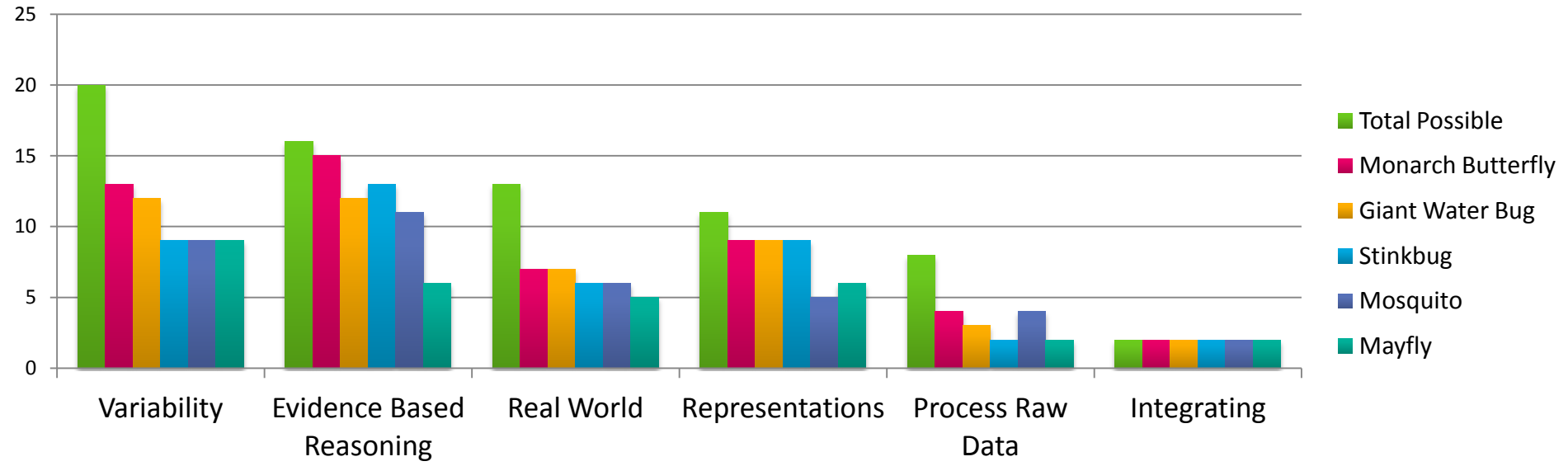
N =310 students

Sources of Variability

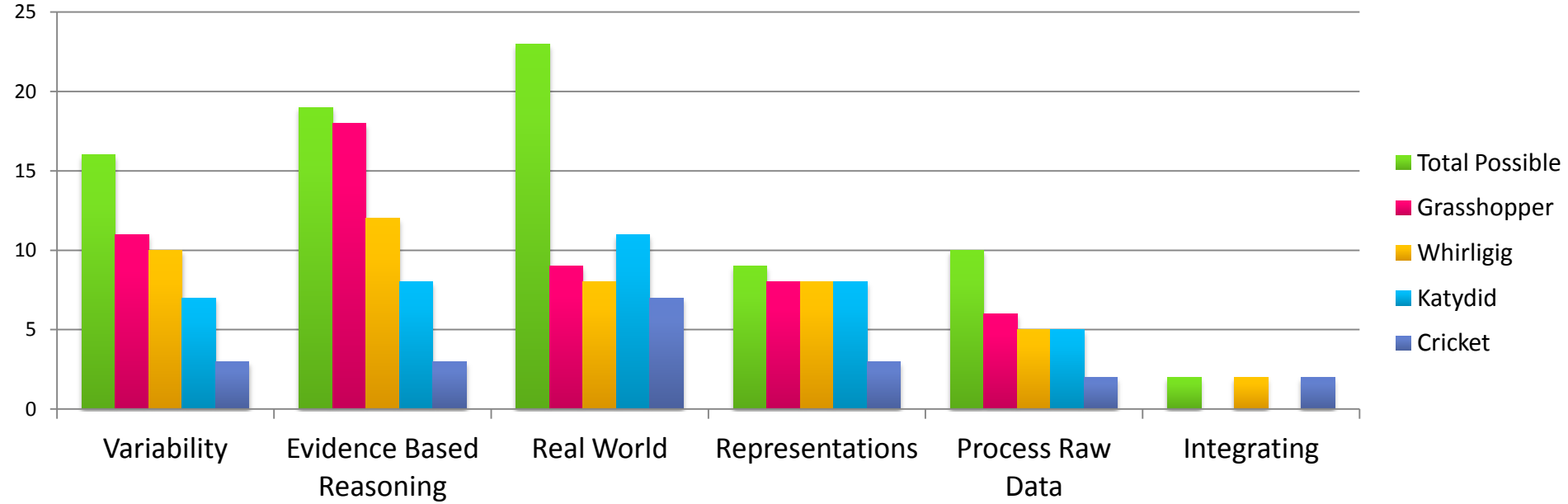


N = 698 responses

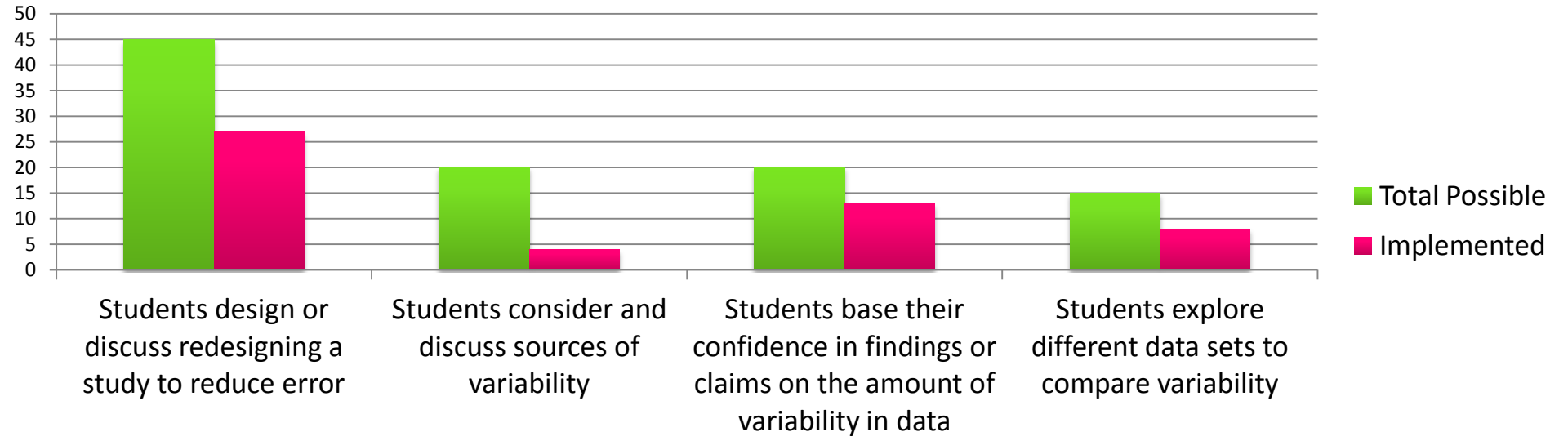
Hydrofracking - Total Possible vs. Teachers' Reported Implementation



Salt - Total Possible vs. Teachers' Reported Implementation



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



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