EDC Education Development Center

AGI american geosciences institute
connecting earth, science, and people

J. Sickler Consulting

Natural Assets for Thinking with Data: Reasoning Strategies & Challenges of 3rd-5th Graders

2021 DRK-12 PI Meeting, June 2021

Presenters: Jessica Sickler (JSC), Michelle Lentzner (JSC), & Lynn Goldsmith (EDC)
PIs: Randy Kochevar (EDC) & Ed Robeck (AGI)
Co-PIs: Lynn Goldsmith (EDC) & Amy Busey (EDC)

This project is funded by the National Science Foundation (grant 1906264). Any opinions, findings, and conclusions or recommendations expressed in these materials are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Study Background and Implications

Study Background & Purpose

Streams of Data is a three-year NSF-funded research and development project to answer: **How can the use of professionally collected, scientific data support the development of data literacy skills in elementary students, and what types of scaffolds are necessary for this potential to be realized?**

The project is using three phases of development and testing:

1. Clinical interviews to identify assets students bring to working with complex data;
2. Formative testing of individual classroom activities for promising instructional approaches;
3. Full classroom testing of a 3-day lesson sequence.

This poster shares findings from Phase 1 (Fall 2019), which focused on understanding the assets 3rd, 4th, and 5th grade students used to make sense of a multivariate problem, using everyday representations of data (rather than mathematical or scientific symbols).

Implications for Practice: Takeaways to Inform Curriculum Design

Even in a clinical interview many students demonstrated abilities to engage in complex reasoning and analytical thinking:

- The majority of students successfully made claims, used evidence, and defended their reasoning about multiple, complex, and contradictory variables.
- Without prompting, the majority of students thought critically about the nature of the data in the problem, asking critical questions about the data and how it was collected
- Students called upon their prior knowledge of natural phenomena to help them make sense of the variables in the problem
- Students expressed verbally that they were challenged by the interview problem, and for many (especially in 4th and 5th grades) it was a "fun" challenge.
- Some older students also explicitly came up with deductive strategies as a process to break the problem into smaller pieces to think through the challenging variables. This suggests promise for instruction around thinking routines for difficult, multi-variable data problems.

Attributes of the interview task that seemed promising considerations for future curriculum:

- **There were no right or wrong answers.** This freed students (and researchers) to focus wholly on reasoning and supporting claims.
- **It used a familiar phenomenon (rainfall).** Students were able to focus on the analytical task because they already had all necessary content knowledge.
- **The open-ended nature of the problem was engaging.** It felt like a riddle to solve.
- **Students were given a set of variables to consider,** with varying relevance to the problem. It added complexity, but did not require students to come up with which variables to consider from scratch.
- **It used qualitative data and relationships.** Using familiar concepts and visual images, students could reason without deciphering symbolic representations such as numbers, tables, or graphs.
- **The problem's complexity gradually increased.** This let students acclimate to the nature of the problem and helped researchers to see where students "hit a wall" in their reasoning skills.

Methods and Study Design

Research Question:
What approaches do students use to reason about information from familiar representations of data?

Protocol: One-on-one clinical interviews with 45 students (grades 3, 4, and 5). Each student was **presented with a series of four scenarios about three children who had collected rainwater in glasses at home.**

In each scenario, students were given new data about conditions of how the rain was collected. Each time, the student had to **decide (and explain) which child would have collected the most, middle, and least water, given the information provided.**

Scenario 1: The intensity of the rain

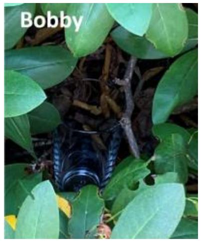
Scenario 2: The intensity of the rain AND how long each rainstorm lasted

Scenario 3: The intensity of the rain AND where the child placed their glass

Scenario 4: All variables: rain intensity, length of time, and placement

Scenarios were given verbally, with photographs (right) as the data for students to consider. Scenarios were designed so that variables conflicted (e.g., longer time with lighter rain).

The images and scenario combinations that students were shown during the interviews.

Anne	Bobby	Cara
Intensity of rainfall was part of each scenario. It was the only variable in Scenario 1.		
		
Length of time of rainfall was introduced in Scenario 2. It was removed in Scenario 3 and reintroduced in 4.		
1 hour of rain	**2 hours of rain**	**Half hour of rain**
Placement of glasses to catch rain was introduced in Scenario 3 and remained for Scenario 4.		
		
Amount of Water Collected (dependent variable)**: Which glass goes with which child, given what we know?**		
		

Defining the Reasoning Codes

Analysis focused on **how students succeeded and struggled in reasoning through the multivariate challenges** (Scenarios 2-4). All children easily mastered Scenario 1; they clearly knew heavier rain would lead to more water captured in a glass.

Coding identified three components in assessing the level of complexity and struggle within reasoning:

a) Number of variables considered
b) Coherence of articulated reasoning
c) Consistency between sort and verbal reasoning.

We arrived at four levels of reasoning, shown below.

Example of Univariate Reasoning:

***Interviewer**: Why do you think those were the matches?*

***Student**: The least [glass goes with Bobby], because of the leaves. The leaves around the glass. And this glass, there was no space for the water to go in there and this was, like, maybe it was a lot of trees around there [the shaded dirt ground picture] so it would fill the cup to the middle.*

***Interviewer**: Why do you think the place where they put the glass matters? It sounds like that was important. Why is that so important?*

***Student**: Because if they put the glass where there are many trees, like this [like Bobby did] then there would be no water in the cup.*

Complex Reasoning	Struggled w/ Reasoning	Univariate Reasoning	Limited Reasoning
• Verbal reasoning shows they considered multiple variables in their choices. • They can articulate how they "connected the dots" between the evidence sources and their choices. • Their sort and their reasoning are consistent with one another.	•Reasoning shows effort to consider multiple variables, but are not fully successful. •They struggle to explain how they "connect the dots" between variables or use interpretations beyond the evidence to arrive at answer. •Their sort aligns with reasoning, even if faulty.	• Do not meaningfully consider a second (or third) variable. • However, their verbal reasoning is very clear; they clearly state how the one variable matters to their answer. • Sort shows the same univariate reasoning as their response.	Struggle w/ all components. •May mention multiple variables, but they aren't clearly considered. •Struggle to explain thinking clearly; train of thought wanders; contradict themselves. •Reasons and sorts may not match and/or reasoning isn't clear enough to judge.

Instances of Reasoning Used

Complex reasoning was the most common type observed. This suggests there is foundational ability within this age group to reason about multiple variables simultaneously.

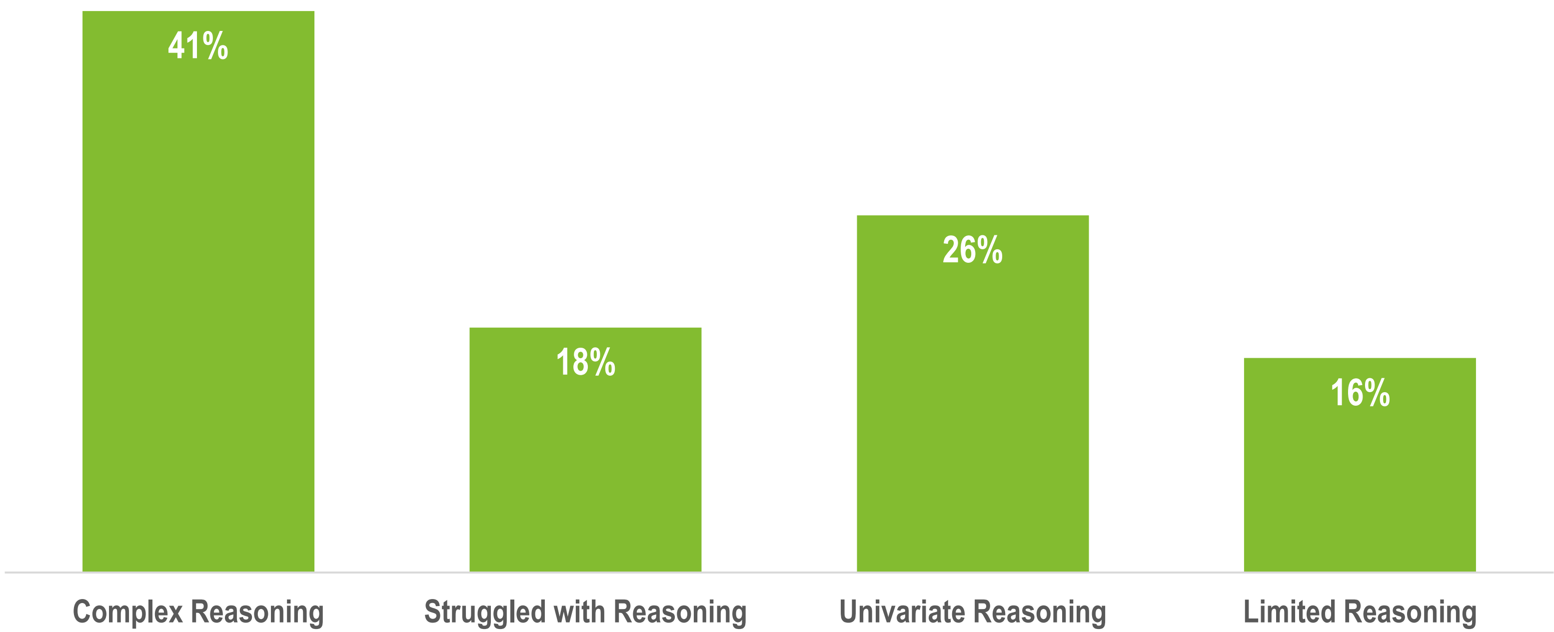
The next most common reasoning was univariate; some students may need help with strategies to coordinate multiple (conflicting) variables in data.

Of the 45 students, 64% used complex reasoning at least once. But only 6 students maintained complex reasoning through all three scenarios.

16 students showed limited reasoning at least once; but only 4 students showed this level of struggle multiple times.

Most students showed a range of reasoning abilities in their interviews.

Fig. 1. How often each category of reasoning was used across all scenarios encountered (n=135 scenarios across 45 individual students)



Differences in Reasoning by Grade Level

Students in grades 4 and 5 tended to use complex reasoning at a higher rate than third grade students. Third-graders showed limited reasoning at a much higher rate, as well as somewhat higher rates of univariate reasoning.

Overall, the fourth and fifth grade students tended to have similar patterns; while there were very slight differences in rates of univariate and struggling, these differences were not substantial enough to be significant.

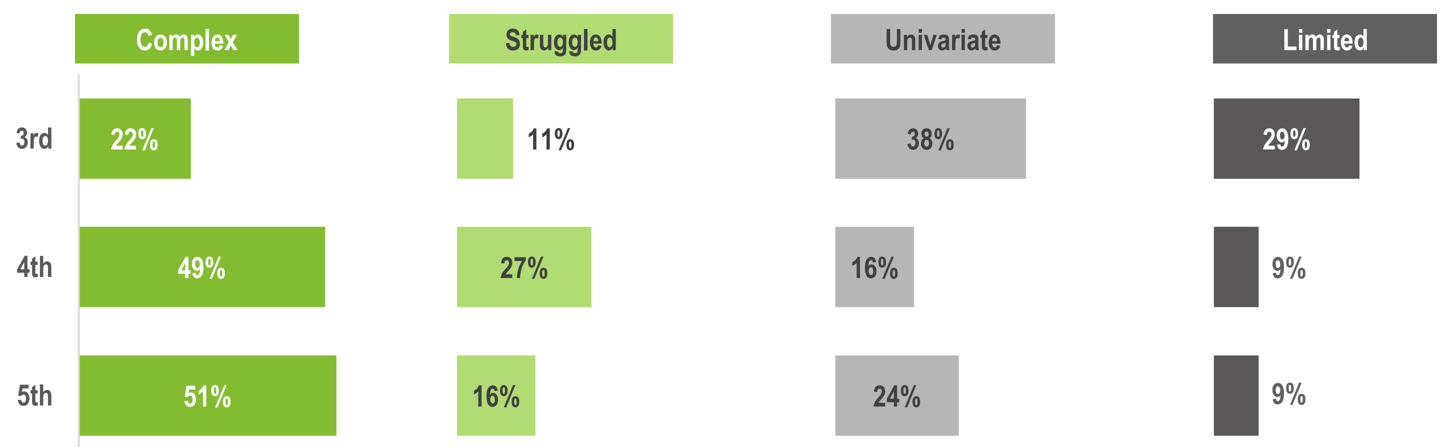
This suggests that **grappling with multiple variables at one time (part of complex and struggled categories) may be a skill that is just beyond the reach of the younger students, but is coming together more fully in upper elementary grades.**

Example of Complex Reasoning:

Student: *I want to keep Bobby's right there. Half hour... I think I'm going to go with this one, because the only reason I wouldn't change these is because they're both on the inside, like outside space. But Cara's was out there more. But they both weren't in the out ... I mean Anne's was outside more and Cara's was only out there for half an hour. And they're kind of in the same space, but they're kind of not. So this one would get less, because it wasn't in there for that long, but this one, it wasn't. But I'm thinking about changing it. Because of rain.*

... But I think Bobby's should just stay there. ...Because it looks like it's under a bush or something. So I know that if it was in the bush, the only way that he would be able to get it is from the leaves. And the reason I'm still thinking hard about Anne and Cara is because Cara wasn't out there for a long time, but now I'm going thinking back to the rain. And in this picture you barely could even see any rain like that. You can only see it like on the sidewalk. It looks like a day after rain. And this one it's raining really hard. And even though she was out there for a half an hour, I feel like she still could get that much from this rain. But I'm going to think about when too, but I think want to stick with it.

Fig. 3. How often each category of reasoning was used across all instances of reasoning; comparing distributions between students in grades 3, 4, and 5 (n=135 scenario responses, 45 responses per grade)



Differences in Reasoning with Multiple Variables

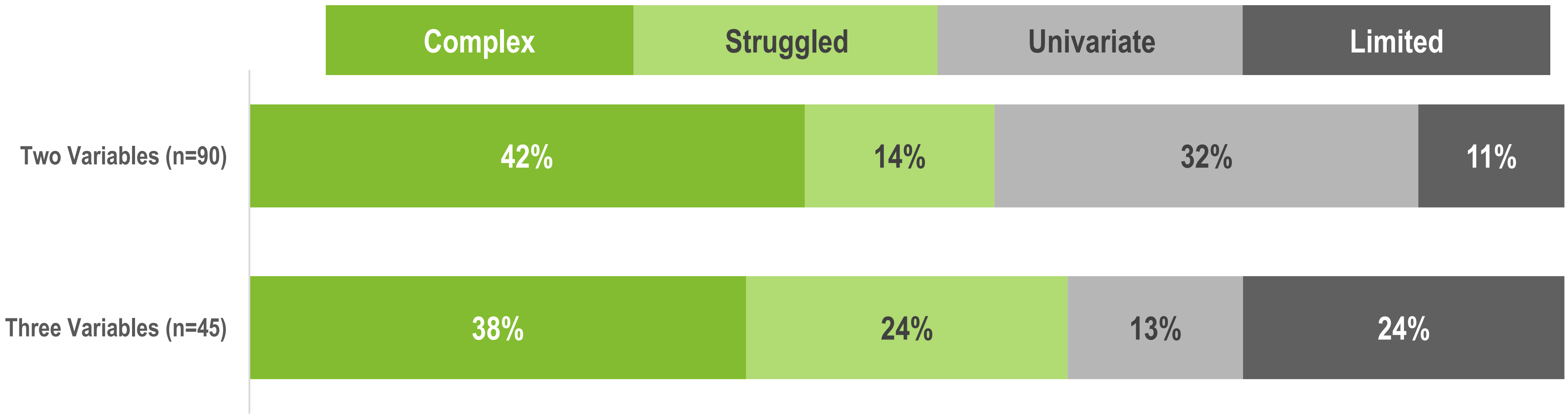
Students often expressed frustration with the challenge when we arrived at the final scenario, which involved three variables. As they looked at three conflicting pieces of information, children recognized they were faced with a tough problem. When we examine how reasoning categories were distributed in the two-variable versus three-variable scenarios, the impact of this additional challenge starts to be evident.

Impressively, **the frequency of complex reasoning was only slightly lower in the three-variable scenario.** And the frequency of univariate reasoning at this stage, however, dropped dramatically.

However, **more students showed limited ability to grapple with the three-variable problem** (mostly among third graders). The rate at which students attempted to deal with multiple variables, but struggled, also increased with three variables.

This pattern suggests introducing the third variable prompted more students to be aware of the complexity of the challenge (i.e., that a univariate explanation was insufficient), even though, for some, this level of challenge made the problem extremely difficult to navigate without educator support.

Fig. 4. How often each category of reasoning was used across all instances; comparing based on which type of scenario was being addressed (n=135, 90 responses in Scenarios 2/3, 45 responses in Scenario 4)



Questioning the Evidence and Scenarios

Critical thinking was coded when students raised thoughtful questions about the data in the scenarios, asked for more information (or data) to help them solve the problem, noted very specific features of the data (images) that led them to make an inference, or questioned a premise or piece of data presented in the problem. All instances of critical thinking coded were unprompted by the interviewer; it occurred in more than half of the interviews.

Students most often thought critically about the placement of the glass, either noting shadows in Cara's photo that might indicate a tree overhead or considering the ways leaves over Bobby's glass would interact with the force of the rainfall. Some questioned whether the amounts of water were accurate for the heaviness of the rain or the intensity of rain in the images.

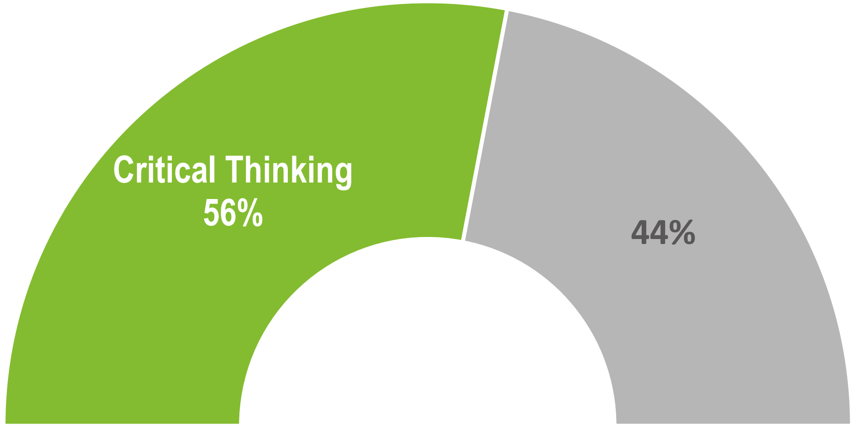
Example of Critical Thinking:

Student*: In this case, because you can tell [in Anne's picture, it] was raining before this; but you don't see any rain falling [in the picture]. So, that's what is kind of questioning me. 'Cause, did they put this picture, did they put the glass out before it just started raining?*

Interviewer*: Okay. So that's what you'd like to know or that would help you decide?*

Student*: Yeah, because it's not raining here [in Anne's picture of light rain]. There's just rain on the ground. So did they put this [glass] in before it started raining?*

Fig. 8. How often critical thinking occurred across all grades (n=45)
Rates at which each student expressed critical thinking about an element of the problem at least once during their interview.



Deductive Sorting Techniques

Not all students showed the *metacognitive process* they used for sorting and decision-making; some simply described their reasoning after making a choice. However, some students either articulated or demonstrated *how* they broke down the problem to arrive at an answer. **The most common (and successful) strategy was Deductive Sorting, which occurred in over 40% of interviews**, especially fifth graders**.**

In this strategy, students made one "easy" sorting choice, and then took longer to work through the remaining choices. It appeared that by "locking in" the first placement they were most sure about (either highest or lowest), it simplified the problem. They could now consider just two sets of variables and weigh the relative importance of their data.

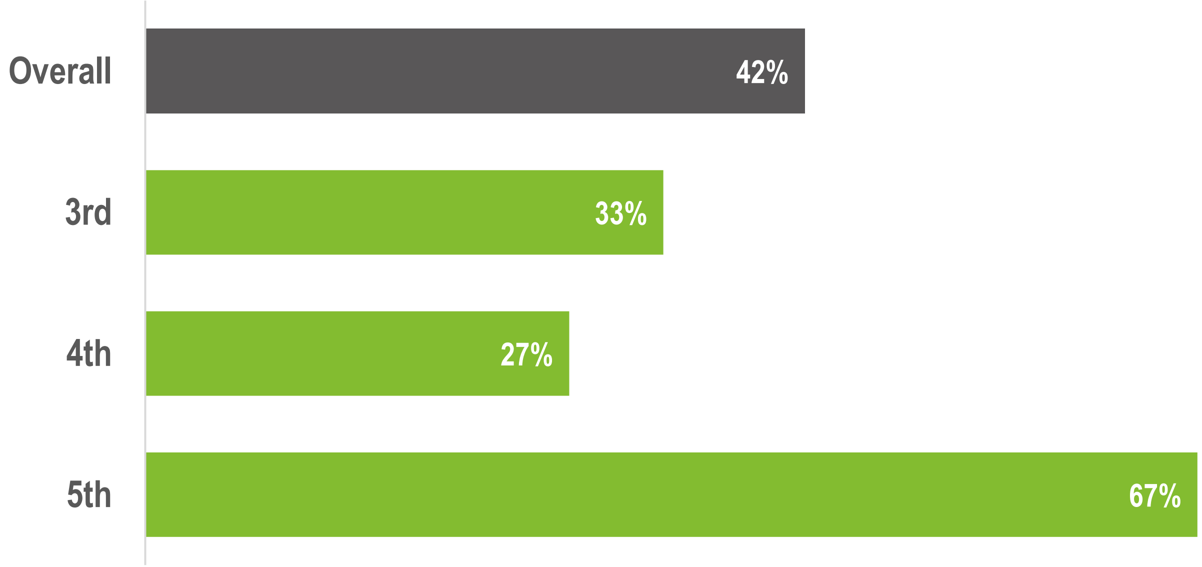
Example of Coded Deductive Sorting:

Student: *I think this one [Cara] should still stay there [as the most water collected]. I'm not sure about these two [Anne and Bobby]. But I'm just going to say, I think they should stay the same [as the last scenario] too.*

Interviewer: *So you think Anne collected the medium amount of water and Bobby collected the least water? [student indicates affirmative] But you're kind of on the fence about that, it could go one way or the other?*

Student: *[indicates affirmative] Because his rained more than hers [which would be more water], but his has leaves over it [which would create less water].*

Fig. 10. Used a Deductive Sorting Approach



Accessing Prior Knowledge and Experience

Some students also made statements that indicated they were drawing on prior knowledge and experiences to reason about the data and problems presented. We coded these connections as either being with science concepts or personal experience.

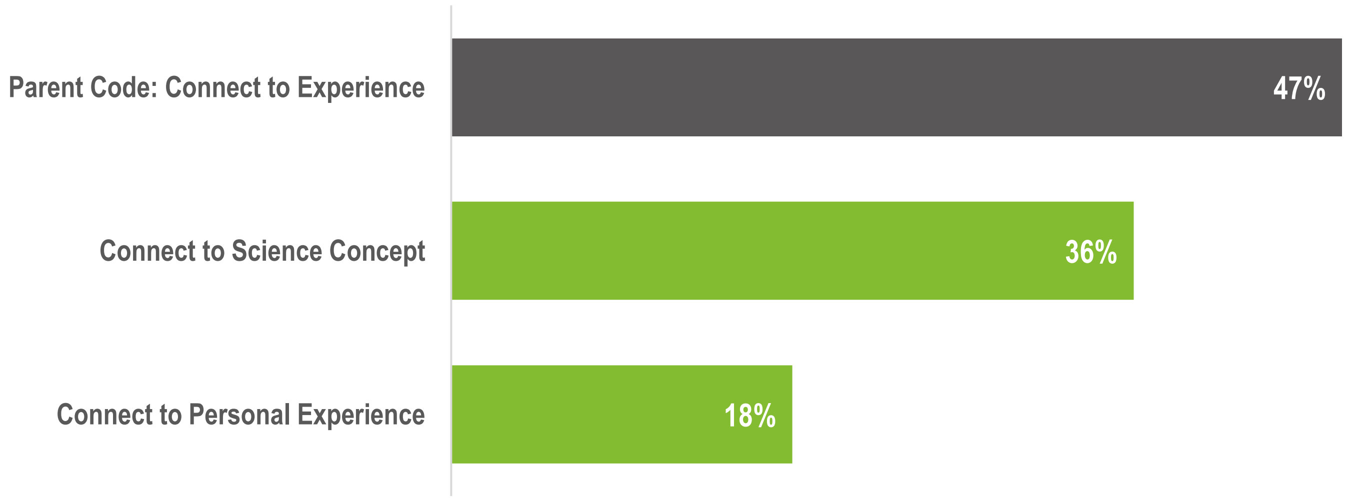
About half of the students accessed prior connections to help reason through these problems. Most often, they drew on science concepts they thought might connect to the problem, including evaporation and climate (e.g., differences between a forest or an arid climate). These came up regularly across all three grades. Connections with personal experience were less common, but included noting familiarity with the different types of rain shown (e.g., "That's May rain").

Example of Connection to Science Concept:

Interviewer: *What do you think I've got here? [referring to Glasses of Water images]*

Student: *Evaporation. ...Because it's from the water, and then it looks like it's the same glass, sitting over time. And it's how a lot of water to less water, and then even less water, because it's evaporating. And this, and the first ones [images of rainfall] would have been precipitation. This one's evaporation first.*

Fig. 9. How often students connected with prior knowledge and past experiences across all grades (n=45)
Rates at which each student connected with a known science concept or personal experience at least once during their interview.



Summary & Implications for Practice

Implications for Practice: Takeaways to Inform Curriculum Design

Even in a clinical interview format many students demonstrated abilities to engage in complex reasoning and analytical thinking:

- The majority of students successfully made claims, used evidence, and defended their reasoning about multiple, complex, and contradictory variables.
- Without prompting, the majority of students thought critically about the nature of the data in the problem, asking critical questions about the data and how it was collected
- Students called upon their prior knowledge of natural phenomena to help them make sense of the variables in the problem
- Students expressed verbally that they were challenged by the interview problem, and for many (especially in 4th and 5th grades) it was a "fun" challenge.
- Some older students also explicitly came up with deductive strategies as a process to break the problem into smaller pieces to think through the challenging variables. This suggests promise for instruction around thinking routines for difficult, multi-variable data problems.

Attributes of the interview task that seemed promising considerations for future curriculum:

- **There were no right or wrong answers.** This freed students (and researchers) to focus wholly on reasoning and supporting claims.
- **It used a familiar phenomenon (rainfall).** Students were able to focus on the analytical task because they already had all necessary content knowledge.
- **The open-ended nature of the problem was engaging.** It felt like a riddle to solve.
- **Students were given a set of variables to consider,** with varying relevance to the problem. It added complexity, but did not require students to come up with which variables to consider from scratch.
- **It used qualitative data and relationships.** Using familiar concepts and visual images, students could reason without deciphering symbolic representations such as numbers, tables, or graphs.
- **The problem's complexity gradually increased.** This let students acclimate to the nature of the problem and helped researchers to see where students "hit a wall" in their reasoning skills.