# Variation & Adaptation of Arts-Based Practices: BIO Implementation

## Research Brief

**Final Report:** 4/30/2025


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BUILDING INSIGHTS THROUGH OBSERVATION

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# BACKGROUND

## Research Overview & Methods

Building Insights through Observation (BIO) was a research and development project to develop a new approach to teaching data literacy by integrating approaches from visual arts education for use with geospatial data visualizations in the middle school science classroom. The resulting BIO framework emerged from a multi-year collaboration between a multi-disciplinary team of curriculum developers, researchers, visualization specialists, and 10 middle school science teachers from around the U.S. The process involved teacher professional development, iterative curriculum development, and research reflection.

**This Research Brief presents findings centered on Research Questions 1 and 2, shown on the following page.**

# BIO Research Overview

**The BIO project aimed to address six research questions within three lines of inquiry – instruction, teacher growth, and student skills.**

This brief addresses the bolded questions. Findings from other research questions can be found in additional Research Briefs.

### Instructional Approaches

**RQ1: Which applications or combinations of arts-based instructional approaches do teachers use and find successful at addressing their curricular needs and goals?**

**RQ2: In what ways do teachers' views and uses of techniques vary, and what does that suggest about the broader potential of this approach?**

### Teacher Professional Growth & Practices

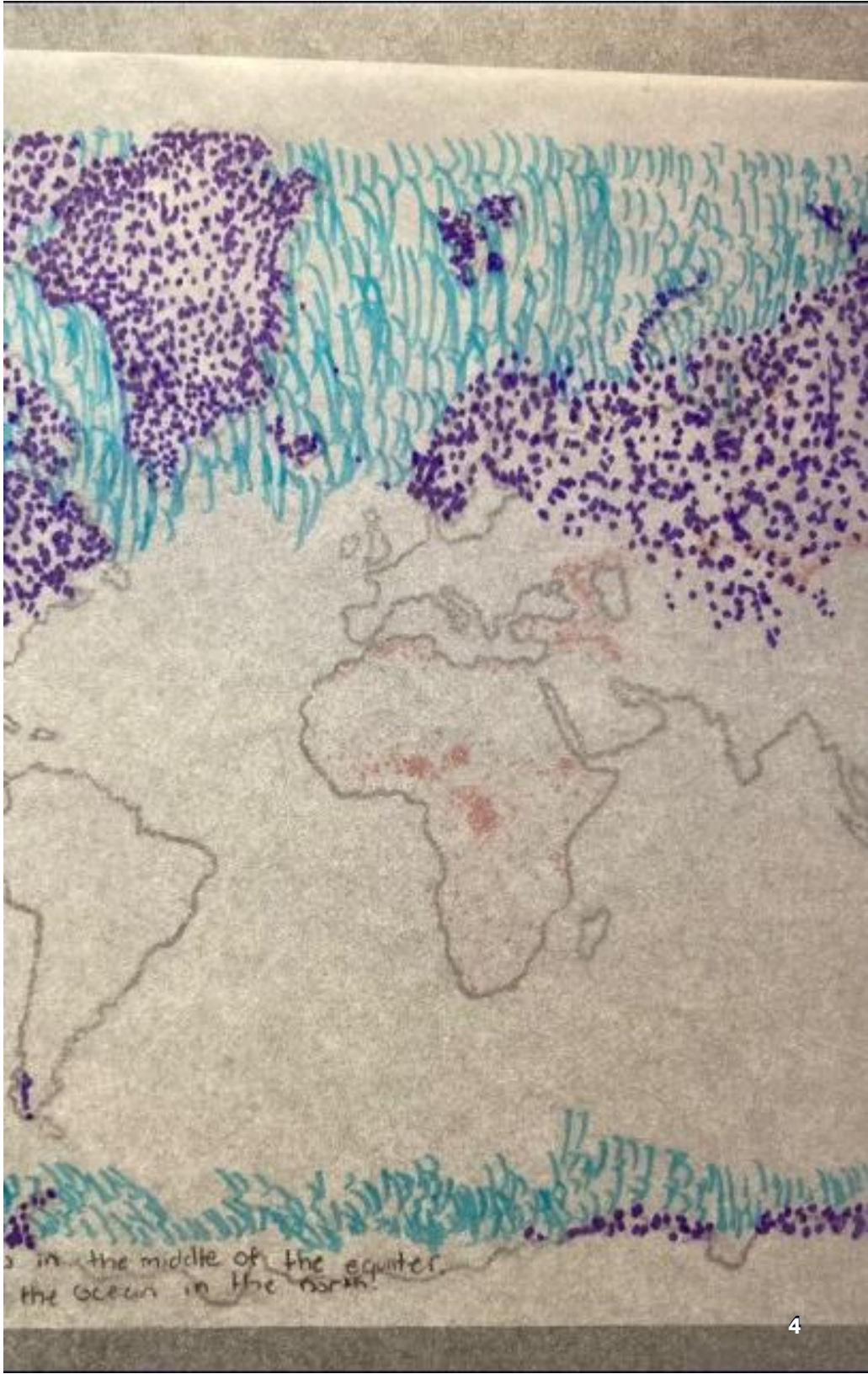
RQ3: In what ways do science teachers develop their professional knowledge and practice, particularly around geospatial data visualization content and pedagogy?

RQ4: What elements of the process of learning, application, reflection, and community-building do they find most influential to their professional growth?

### Promise for Developing Student Skills

RQ5: When arts-based approaches are applied in science classes, in which of the data/visual literacy skills do students show the greatest growth?

RQ6: Compared to standard instruction, do any skill areas show particular promise of being influenced by the arts-based approach?



# BIO Research Overview

**This Research Brief presents results from examination of the classroom implementation of BIO lessons during the 2023-24 school year, including strategies teachers used during the lessons and outcomes of those choices.**

The Building Insights through Observation project was implemented in partnership with 10 middle school science teachers from around the U.S. Two cohorts of teachers participated from 2022 to 2024. The timeline of PD experiences within BIO was as follows:

- **2021-22 School Year:** Pre/Post student data performance tasks and interviews (control) were completed from Cohort 1 teachers' classes
- **Summer PD 2022**: Cohort 1 initial 3-day Workshop (Easton, PA)
- **2022-23 School Year Implementation**: Cohort 1 members created and implemented 2 lesson plans per teacher; Project team provided coaching, advice, and technical support; teachers submitted reflections after each implementation
- **Summer PD 2023**: Cohort 2 & Cohort 1 at 3-day Workshop (Easton)
- **2023-24 School Year Implementation**: Both Cohorts' members created and implemented 2 lesson plans per teacher; Project team provided coaching, advice, and technical support; teachers submitted reflections after each implementation; Pre/Post student data performance tasks and interviews (intervention) are completed with students from Cohort 1 teachers' classes
- **Summer PD 2024**: Culminating workshop to reflect on critical elements of the curricular model, PD, and developing resources for teachers fieldwide


**RQ1: Which applications of arts-based instructional approaches do teachers use and find successful at addressing their curricular needs and goals?**

**RQ2: In what ways do teachers' views and uses of techniques vary, and what does that suggest about the broader potential of this approach?**


BACKGROUND

# Research Methods: Implementation

### Data Source: Teacher Surveys & Interviews

Teachers provided reflections and feedback on their PD experiences and the overall model throughout their work with BIO. Teachers responded to a year-end survey and a one-on-one interview in each year of the project. This means that feedback was received from Cohort 1 at the end of their first year (midpoint) and at the end of the project's second year (post). All teachers completed all surveys and interviews.

Related to implementation, the final post-survey asked teachers to reflect on the likelihood they would use BIO lessons in the future and their perceptions about how BIO lessons impacted their students.

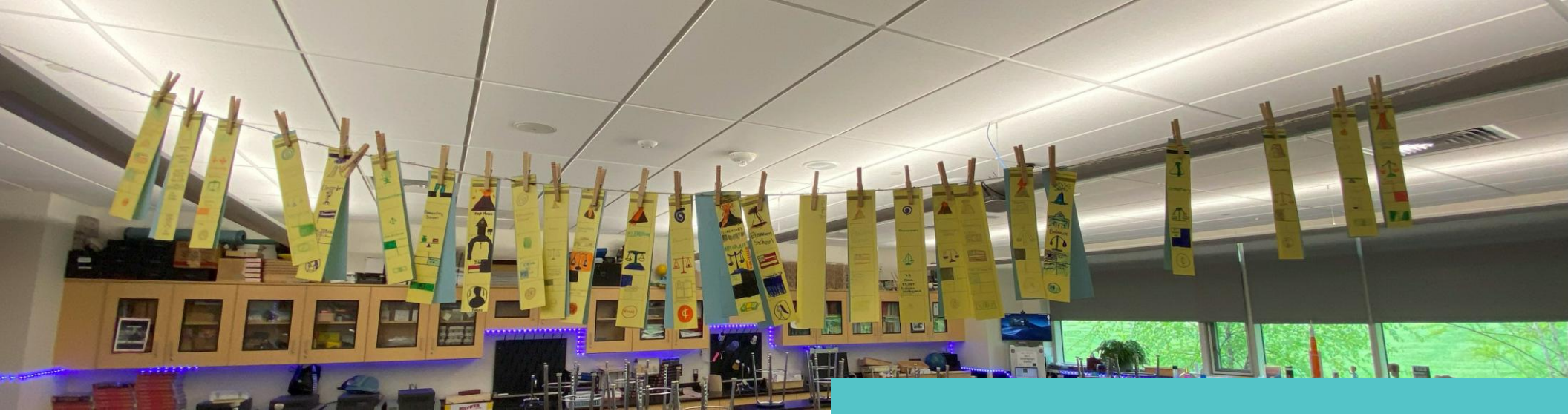
Interviews explored teachers' takeaways about student impacts, their implementation choices, and their future plans for using BIO lessons in greater depth.

### Data Source: Teacher Reflections

In the final year of implementation, teachers filled out a form after each BIO lesson responding to closed-ended questions about specific implementation strategies, as well as open-ended reflections about how each lesson went. At the 2024 Summer Workshop, teachers were provided with visualizations of these data and participated in a meaning-making session where they reflected on the strengths and limitations of their implementation choices to provide additional insight.

### Data Source: Student Interviews

Students who participated in a study of student data literacy skills (from Cohort 1 classes) engaged in a task-based interview before and after two iterations of BIO lessons. At the end of the post-BIO task interview, students were asked to reflect on what they liked and disliked about the BIO lessons, as well as what they learned about data and maps. Their responses about likes, dislikes, and learning are reported here.



BACKGROUND

# Data Analysis: Implementation

## Quantitative Analysis

Teacher survey data and closed-ended reflection data were analyzed descriptively, exploring the frequencies of ratings by the 10 teachers in the final survey of the project.

Closed-ended reflection data on implementation was visualized into flow charts to characterize the variation in how teachers from both cohorts approached BIO lessons in their classrooms in the final year of PD. Those charts are presented and discussed in this report, alongside other quantitative data on time spent and other notable variations in classroom teaching and implementation.

## Qualitative Analysis

All interview data and open-ended response data, including student interviews and some teacher reflection data, were analyzed using a general inductive approach.

Preliminary coding of qualitative data occurred throughout the project to inform the curriculum development team as they refined the PD model each year. This initial coding was guided by the targeted interests of the project and emergent themes from early datasets. The project team and teachers reflected on the data at several different times throughout the project. Their insights from reviewing data informed revisions to the codebook.

The final codebook was developed and finalized after all data were collected and input was received from participants and team members. All transcripts were then reviewed and recoded, using this new framework. This report presents results of this final analysis of data.

# BIO Lesson Overview

**BIO implementation centers around three key activities, plus a culminating discussion, designed to integrate visual thinking skills, design thinking skills, and content understanding to develop data literacy using arts-based practices and professionally collected geospatial data.**

### 1.) Discussions inspired by Visual Thinking Strategies (VTS)*

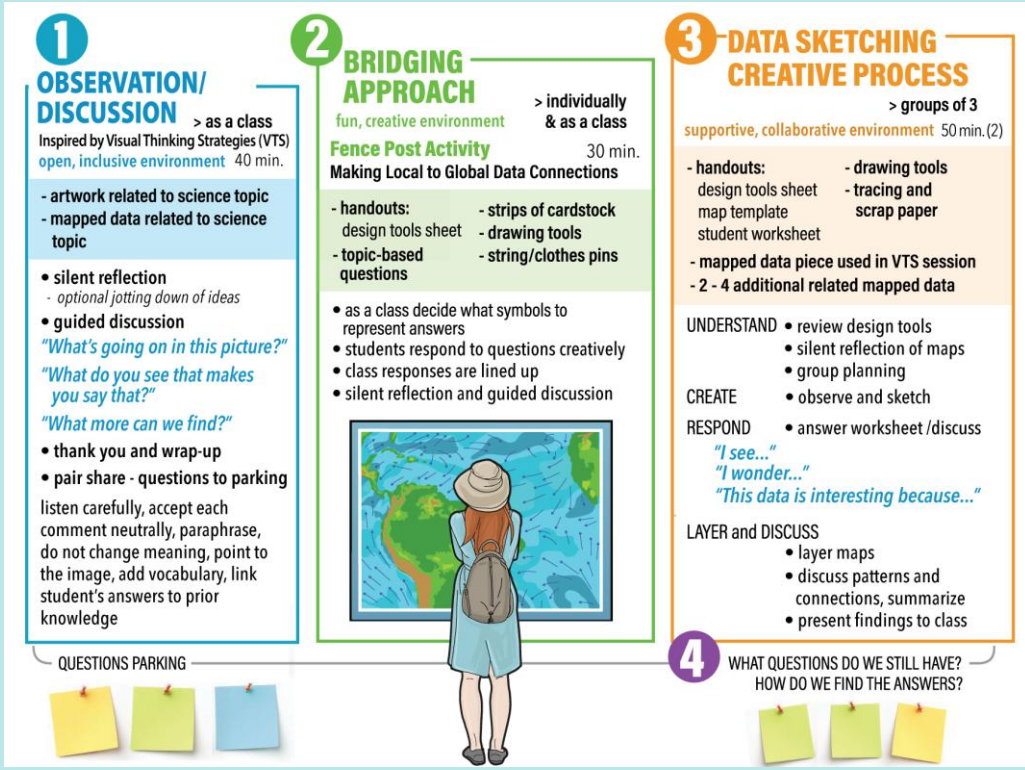
As a class, teachers guide students through a carefully facilitated discussion, first about a piece of artwork and then about a data visualization, using the VTS technique. Discussions are open-ended, generating interpretations and observed evidence to support them.

### 2.) Fenceposts

Students respond to a series of five teacher-designed poll questions, about their personal experiences and opinions related to the unit's topic. Students visually represent their individual answers on slips of paper using agreed-upon symbology (based in Design Tools). Class responses are lined up like fenceposts to generate discussion about the visual patterns that come from symbolic representation of data.

### 3.) Data Sketches

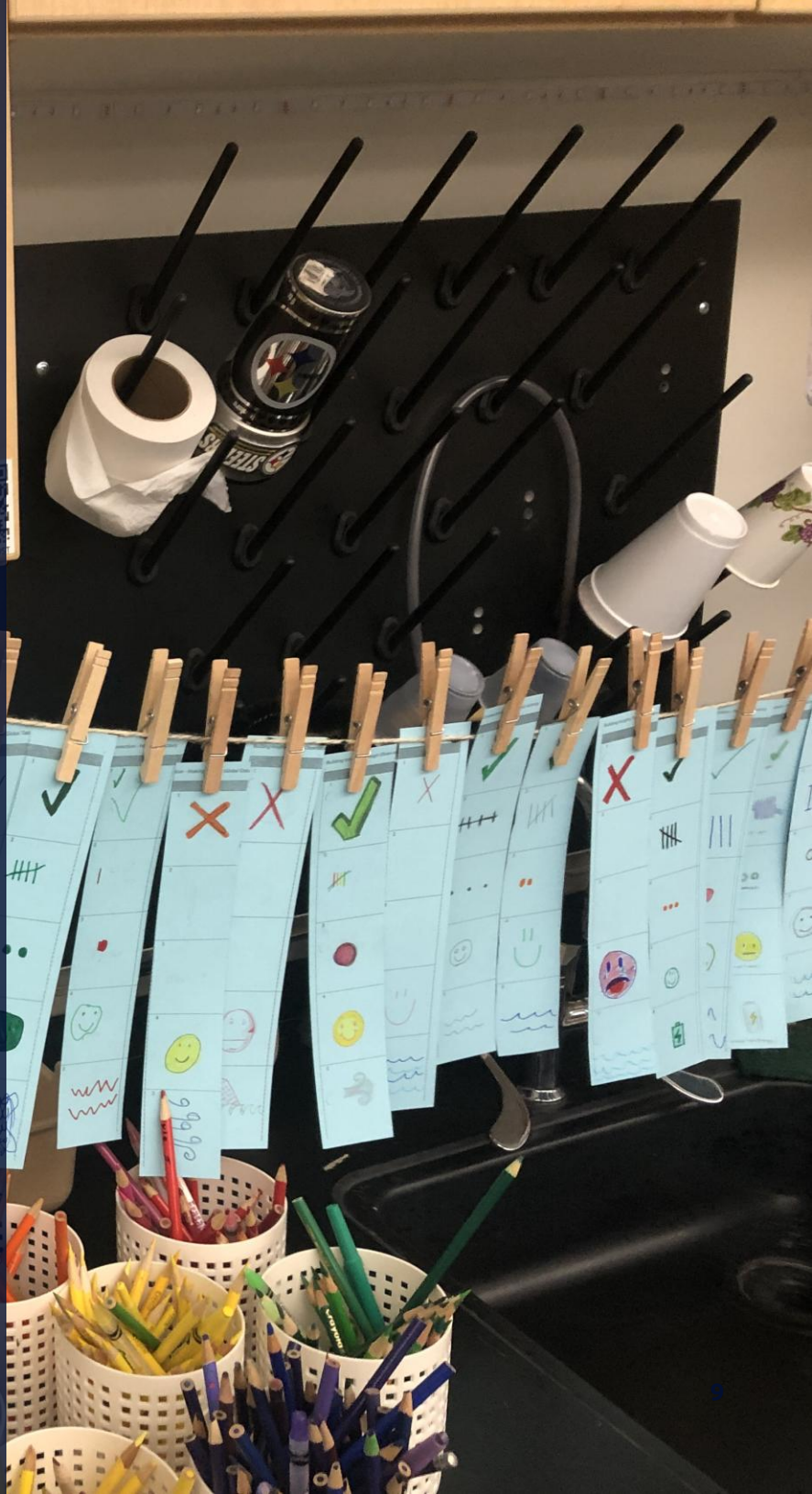
Each small group receive ~3 visualized geospatial data sets. Students are tasked with identifying ways to re-visualize each of the data sets using different symbology than the original. Each student resketches the data from one map on tracing paper. After sketching, students layer and compare their visuals, looking for correlations, patterns, and other notable features. Finally, discoveries are discussed as a whole class.




*VTS (https://vtshome.org/) is a well-established and highly researched arts-based discussion approach, traditionally used to generate ideas about artworks, notice details, and make new and surprising connections.

# RESULTS

## Implementation of BIO Lessons



# VTS-Inspired Discussions: Implementation Strategies

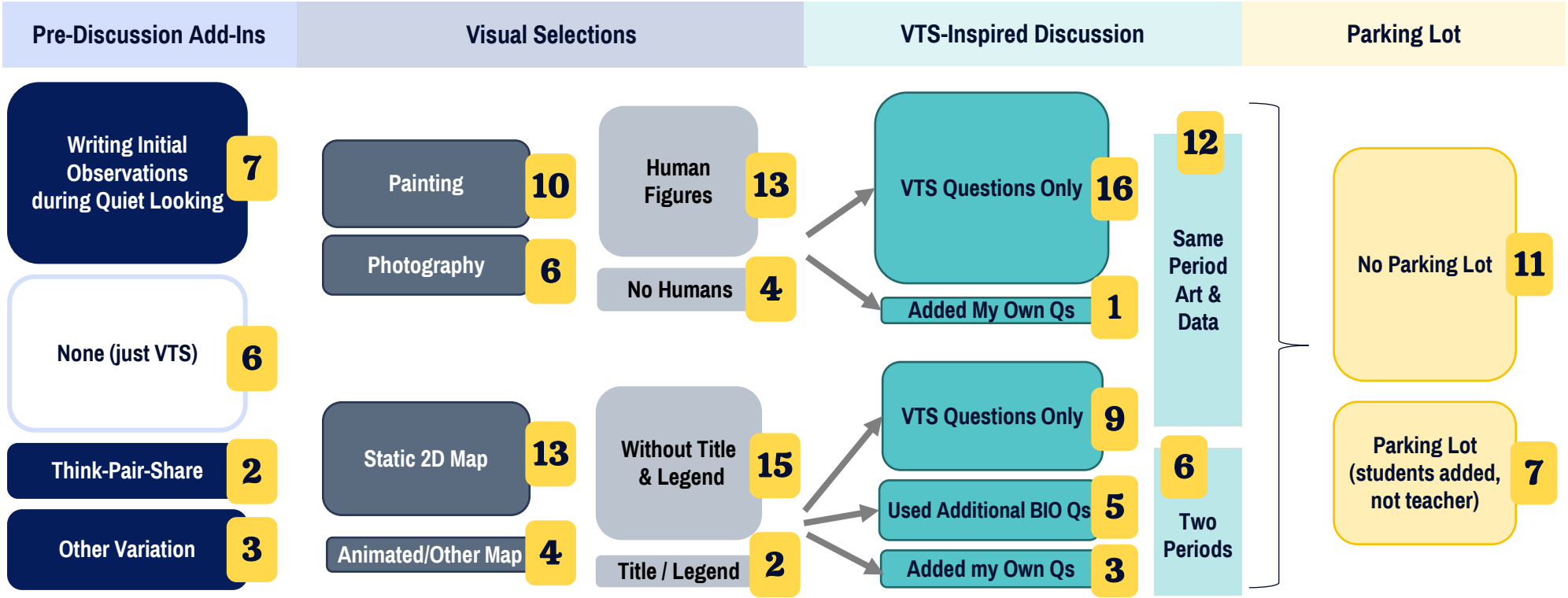
**Teachers' implementation varied the most in three areas: pre-discussion stage-setting, if additional questions were asked in the data portion, and use of the parking lot.**

Teachers also tended to diverge on whether they did both discussions in a single class period or spread them over multiple days.

For artwork selection, there was a mix of painting and photography, with most teachers sticking to the advice from BIO PD to include human figures. For data, nearly all used a static 2D data map and withheld the title and legend for the start of the discussion. Teachers were more faithful to only using VTS questions with art, but a few tried additional support questions during data discussions. Most teachers did not use the idea "parking lot" for students to add their questions.

**Variations in implementation of VTS-inspired discussion over two iterations.**

Data from teacher reflections immediately after implementing in the 2023-24 school year. (First iteration, n=10; second iteration, n=8)



# Teacher Reflections: VTS Discussion Implementation

"They started out with just general observations, then got quite creative as the discussion went on. This could be because I was really enjoying the interaction and decided to extend it to get more participation**. I definitely feel more comfortable with the process now that I have done the VTS with multiple students in multiple classes**. Experience and practice: There really is no substitute!"

-Teacher Reflection

"**I was really pleased at the high level of participation** from [the class]. They really seem more comfortable looking at this type of data and trying to make sense of it. I made the decision to do some "cold calling" of reluctant students which mostly worked in terms of eliciting responses from almost every student."

-Teacher Reflection

"With different classes, **I had a diverse experience with all the students depending on what they saw** and their prior knowledge."

-Teacher Reflection

"I definitely like the open-ended aspect of the VTS. **The 'open-ended, no right answers' is perfect for helping kids to generate observations.** And what do you see that makes you say that? Supporting observations with evidence. That whole approach was great in terms of teaching the skills of the science and the content … but it was kind of taking those skills and that approach and applying it to a different setting, which I also did find … that people who were maybe less talkative overall kids would chime in and say things. And so that was very valuable, I think."

-Teacher Interview

"Just speaking to the VTS, **what was so powerful for me was what other people were seeing that I wasn't seeing and getting different perspectives on the data or the artwork** or whatever, and slowing down and listening to what other people had to say and not looking for the right or wrong answer. And [not,] 'I'm going to get the gold star because I answered first and I could say the most'. I just think it definitely changed classroom culture."

-Teacher Interview

"**The parking lot questions were interesting** - surprised by the number of students that could only come up with flood prevention as a reason for reservoirs. Some said store water for human consumption. The concept of storing water for agriculture did not come up and for my student population. **I was surprised**."

-Teacher Reflection

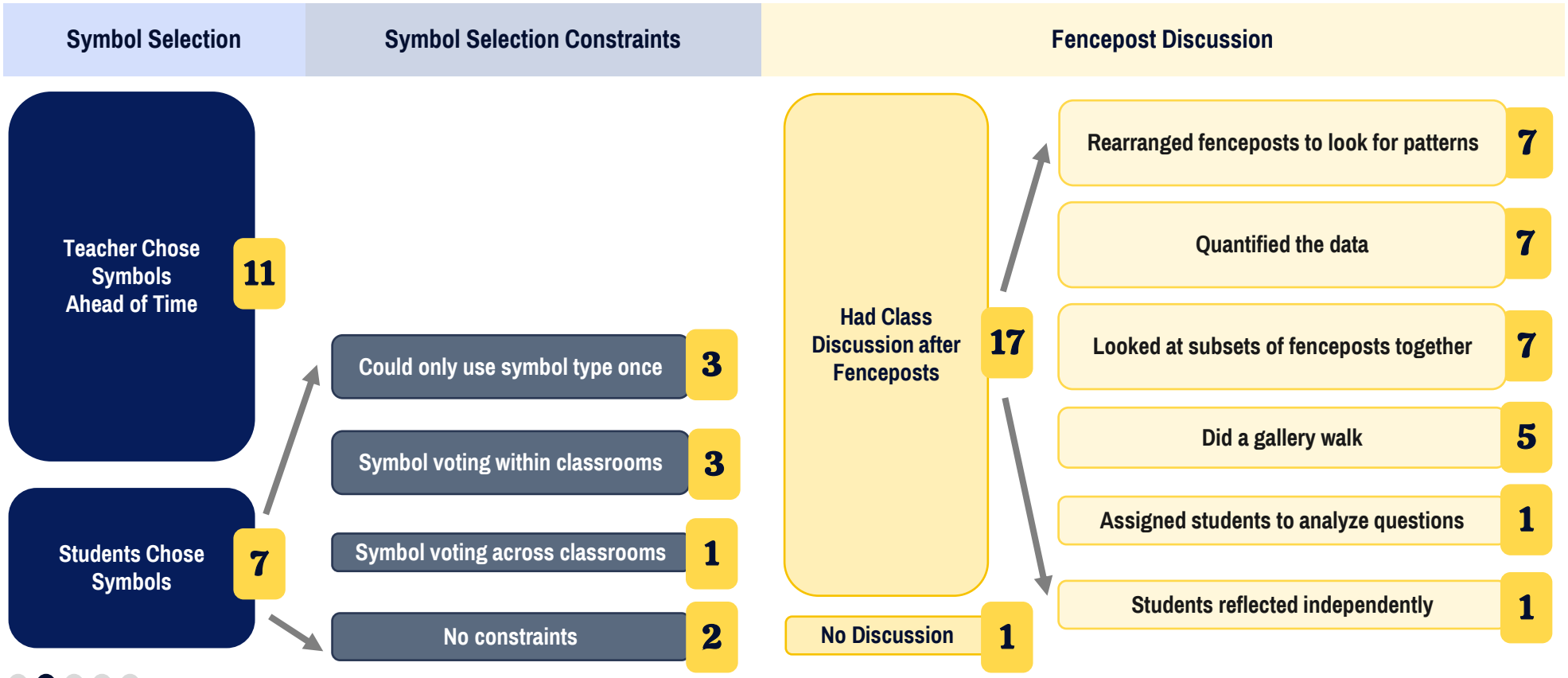
# Fenceposts: Implementation Strategies

**Most teachers opted to choose fencepost symbology for the activity, without student input; a strategy that saved time. All but one implementation spent time looking for patterns, quantifying, or rearranging the fenceposts during discussion.**

Among teachers that used the strategy of having students choose their own symbols, most also created some constraints to prompt critical thinking about symbol choices. Those constraints included symbol types or voting on options of design. Nearly every iteration included a post-activity discussion, in which students explored the data in a variety of ways.

### Variations in Fenceposts implementation over two iterations.

Data from teacher reflections immediately after implementing. (First iteration, n=10; second iteration, n=8)



# Their Words: Fenceposts Implementation

"6th grade took much longer and had a harder time understanding the task of picking the symbology being used. **They became very fixated on answering the questions, and thought I was looking for the "right" answer**. It helped that they were in small groups and I was able to circulate around to clarify."

-Teacher Reflection

"The fencepost stuff was good. I mean, the big problem I had with that was symbology because in some of the symbols, students chose. When students went to draw them on the fenceposts, we had to create a master key to remember what the symbols were, because the way some of the kids drew some of the symbology we put up on the fence post. It was hard to tell what they chose. And **the drawing was all over the place. And then, so that needed to be simplified a little bit**. "

-Teacher Interview

"I think, **having done this for a second time**, and having done several other activities around data, made the **students more tuned into the value** of this kind of thinking."

-Teacher Reflection

"Thought it was important to return to the VTS process [during the Fenceposts discussion]. What do you see, what evidence do are you using to support your observations. **I think it is important to have each individual reflect before sharing out in a group discussion**."

-Teacher Reflection

"I'm going to do the fenceposts a lot [after the PD ends]. I think because again, it was getting them just to think about their answers in a different way and making them think about how data can be represented. … **They loved getting to choose the symbols, and it was fun to hear their reasoning behind the symbols**."

-Teacher Interview

"The students liked looking for patterns, but struggled to identify some answers with symbols like values and intensity. This, however, **led to good discussions about when and when not to use those symbols**. Especially since they were used in the visual data set we used, and it was much more helpful in that instance. I think next time I might pre-emptively decide what kind of symbol to use, and then let them determine the exact symbol, color, etc."

-Teacher Reflection

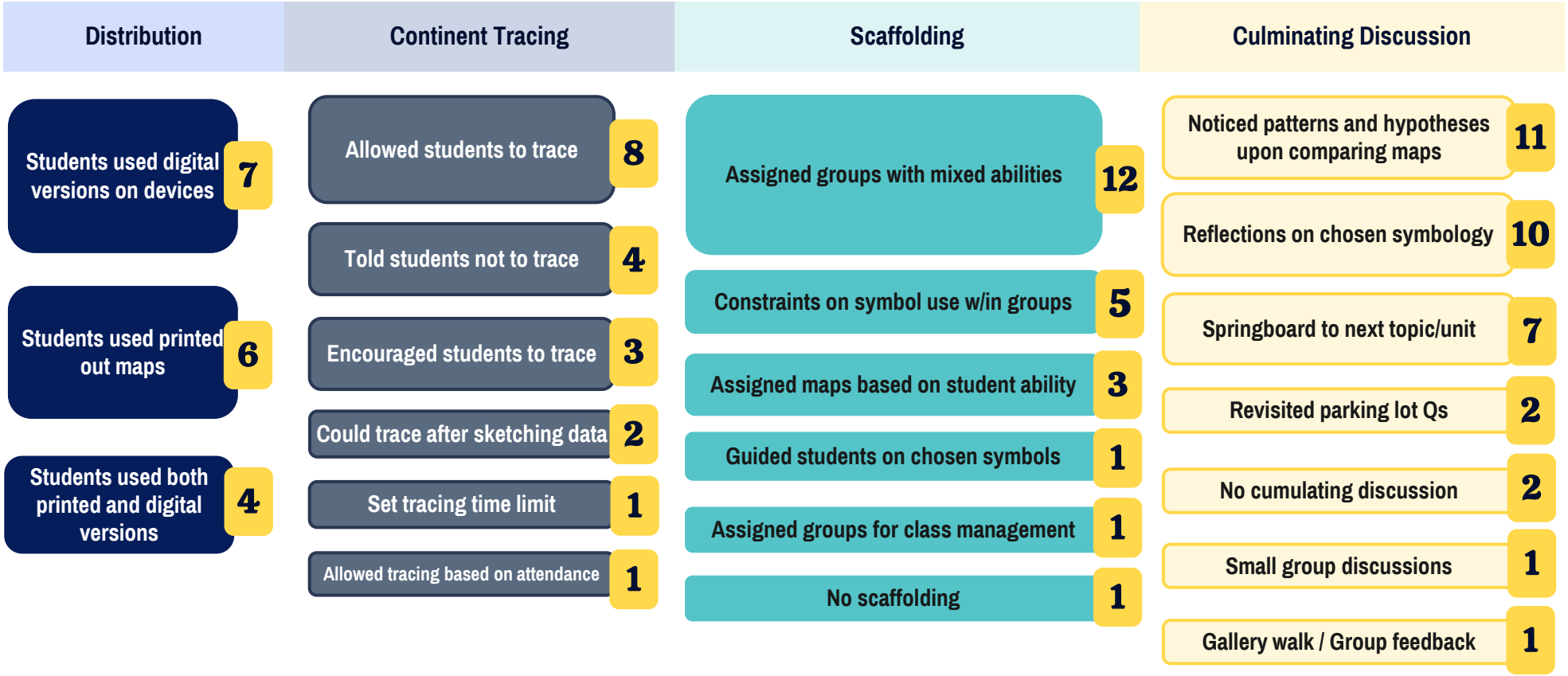
# Data Sketches: Implementation Strategies

**Data Sketches showed the widest range of implementation strategies. Most used the strategy of mixed-ability groups to promote peer learning, but implementation varied a great deal.**

A common pinch-point was students' impulse to begin by tracing continents (before sketching data). Most often teachers allowed or encouraged tracing to start; it was often a safe entry point. Teachers that told students not to trace often reported students disregarding that instruction. Teachers used a mix of digital and paper maps and different scaffolding strategies. All but two teachers had a culminating discussion.

## Variations in Data Sketches implementation over two iterations

Data from teacher reflections immediately after implementing. (First iteration, n=9; second iteration, n=8)



# Their Words: Data Sketches Implementation

"In the whole group discussion, it became evident that **the groups were not in total agreement as to correlations that existed in the data - which was good**. The parking lot discussions was excellent. A new set of questions was developed as it related to our weather/climate unit."

-Teacher Reflection

"When we did the data sketches and the follow-up activities... Even with the data sketches, going back and **looking at your own map as you got done, does that actually reflect the data the way you intended** or was your drawing rushed? How complete was that? And just again, using it as a tool to evaluate that ... and saying, okay, let's look at it. Does this make sense? And so, coming back in, yeah, you got to draw, you got to do this by hand and everything else, but does what you did reflect what we want to do?"

-Teacher Interview

"The discussion was productive but **because the data I chose didn't have many strong correlations, I think the students felt "pressured" to find connections that weren't there**. But there was a lot of close investigation looking at comparisons of the data. I think I should have had more focused questions around the data tool choices as that part of the discussion was pretty weak."

-Teacher Reflection

"I very much think that familiarity that the students had with the process and the level of comfort that I had leading them through it very much offset [lack of experience with maps and data]. In other words, **practice and experience seems to trump everything else when leading students through the BIO process**. Teachers absolutely need to try this more than once with their classes in order for students to see the benefits."

-Teacher Reflection

"If I were to allot class time to tracing the maps again, **I would want to team up with a geography teacher so that the maps could be assessed in some way** or be utilized to teach geography."

-Teacher Reflection

"And then with the maps [for data sketches], **I think the tracing [the continents], the amount of time the tracing took, I feel like if it'd be possible to get ... pre-printed world maps ... and I even thought about trying to see if I could get someone to 3D print**, I can take, do a cray rubbing ... or just get a big stamp."

-Teacher Interview

# Variation in Time Spent on VTS & Fenceposts

### The median time spent on VTS-Inspired Discussions was the same for both art and data – about 20 minutes each.

Teachers typically estimated that they spent 20 minutes on each VTS discussion, with art and with data. **The median total class time for this component of BIO was 40-45 minutes**. This was the BIO lesson element with the least variation in the time to implement it. However, there were a few outliers in implementation – including 2 implementations in each where the teacher completed the discussion in ~10 minutes (about half as long as was recommended). Some teachers spent even longer than 20 minutes.

| (n=17) | 10 mins | 15 mins | 20 mins | 30 mins |
|---|---|---|---|---|
| Art | 2 | 3 | 8 | 4 |
| Data | 2 | 4 | 8 | 3 |

"Just that I wish I had done the parking lot [following VTS]. It was my first time doing this and I was excited and a little worried about running out of time. I might show the image[used for VTS] again at some point or elicit questions about it another way."

-Teacher Reflection

### Teachers spent wide ranges of time doing Fenceposts with their students from 30 to almost 80 minutes of class time.

Most teachers spent fewer than 50 minutes on this activity, but a handful of implementations lasted longer than an hour (generally taking more than one class period). Based on written reflections, the main factor in how long the activity took was whether students were asked to choose and/or vote for their own symbols. Teachers who opted to create symbols for their students to use could complete the activity faster. Teachers who put students in that role took longer, but often found it helped with sparking student thinking about the options, pros, and cons of different visual symbols for representing data.

| (n=18) | 30-39 mins | 40-49 mins | 50-59 mins | 60-69 mins | 70-79 mins |
|---|---|---|---|---|---|
| Fenceposts | 4 | 6 | 3 | 3 | 2 |

"We did [Fenceposts] fairly quickly. I think I would spend more time on it next time. We were able to see the big ideas/patterns, but I would like to try a gallery walk next time."

-Teacher Reflection

# Variation in Time Spent on Data Sketches

**Time spent on Data Sketches showed the widest variability, with some teachers spending one full class period (or less) and others devoting three or more class periods to the lesson.**

The time estimates provided for this activity included all of its components, including group work sketching the data, layering the sketches in small groups, and a whole-class discussion about student takeaways and discoveries. The median time was 90 minutes to 110 minutes – but the range of time spent was extremely wide, and inconsistent.

Teachers **most often spent around two class periods on Data Sketches**, which typically amounted between 70-110 minutes. A few teachers spent much longer on this activity, with one teacher digging into the activity over four class periods. In addition to time in class, some teachers assigned unfinished sketches as homework.

Examining reflections, we saw that differences in length often related to depth of the culminating discussion. Some teachers invested substantial time in revisiting the parking lot of questions (from Part 1) and transitioning the BIO lesson into next steps for their unit of study.

| Minutes (n=17) | 30-49 | 50-69 | 70-89 | 90-109 | 110-129 | 130-149 | 150-169 | 170-189 | 190+ |
|---|---|---|---|---|---|---|---|---|---|
| Data Sketches | 3 | 1 | 2 | 4 | 1 | 1 | 3 | - | 2 |

| Data Sketches: Class Time vs. Homework | |
|---|---|
| We did it all in class | 9 |
| Tried to finish in class; some took it home | 4 |
| Students had to finish their sketches at home | 3 |
| Students could trace continents at home | 1 |

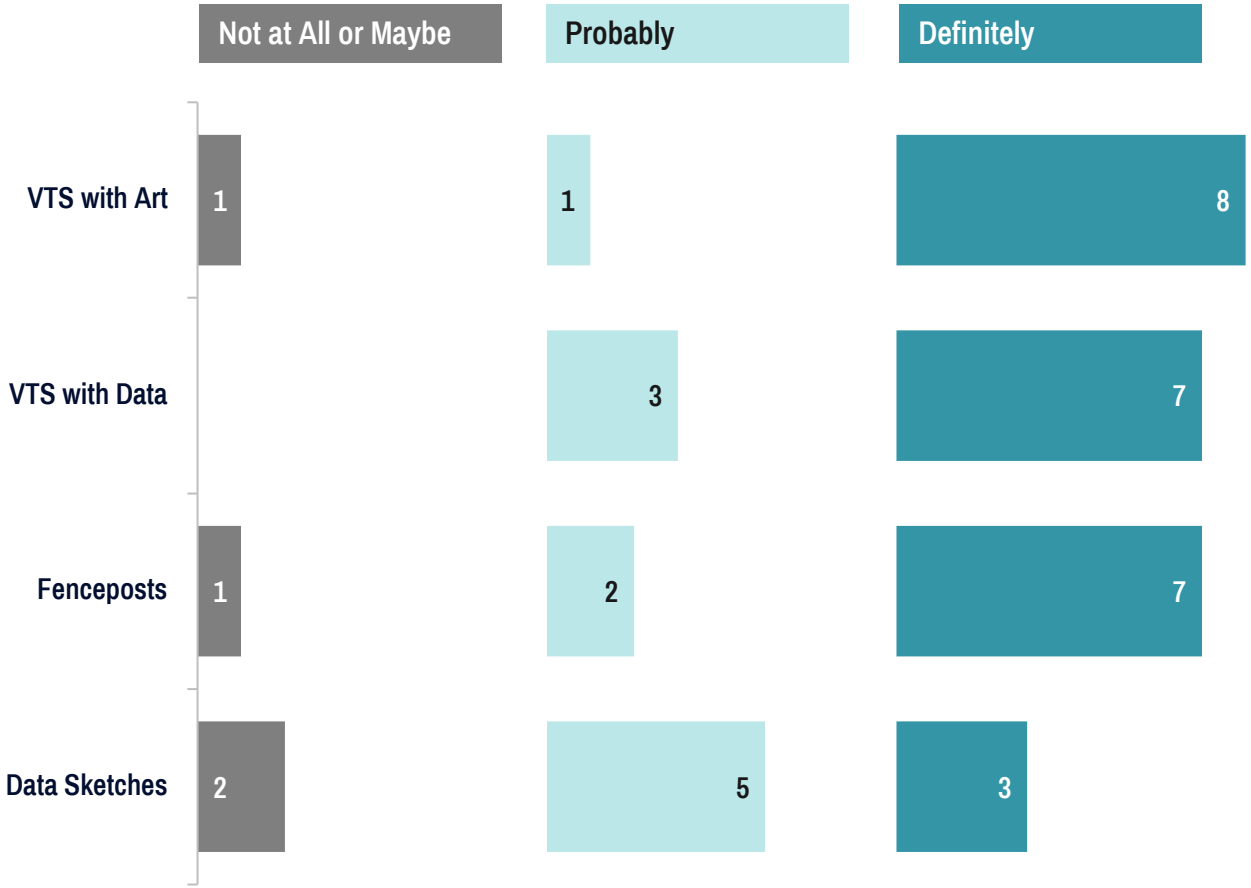
"The discussion was very rich, and I was pretty psyched about it! However, we ran out of time! I also gave them the individual reflection as an assignment which I think prepared them well to share with their group."

-Teacher Reflection

# Likelihood of Using BIO Lessons in the Future

**Teachers' self-reported likelihood to use each of the BIO lesson elements in their future teaching.**

After the PD concluded, teachers were asked via survey to rate their future likelihood to use each lesson type on a 4-point scale, with 1 being Not at All to 4 being Definitely.




**VTS-Inspired Discussions and Fenceposts are most likely to be used beyond the BIO project by the trained teachers. Data Sketches received more equivocation about if or how teachers would use it again.**

VTS with Art was the BIO lesson element that the most teachers felt certain they would keep doing, even without the requirements and support of the BIO project. Only two of ten teachers felt less than sure they'd repeat it.

VTS with Data and the Fenceposts also felt very replicable for teachers. In interviews with teachers, they described many 'outside of the box' ways they intended to keep using Fenceposts, beyond the context of the BIO lessons or explicitly teaching data skills. This included using it for ice breaker activities, pop quizzes, and other ideas.

Teacher commitment to using Data Sketches was mixed; half of teachers felt they'd probably use the activity again, but weren't sure. The time it took was a barrier, even when they saw benefits. Some teachers were interested in changing or adjusting Data Sketches in tactical ways, including using state or local maps – instead of the global view.

# Their Words: Using BIO Moving Forward

"I do think two [yearly iterations of BIO lessons] is good. … they were kind of like 50/50 when I did the second [Data Sketches this year]. … The rest totally takes no time at all. So, they're always down to look at art, always down to look at the data and discuss it. The Fenceposts were super cool. They love looking at that. Obviously, I want to improve on that more. But yeah, the [Data Sketches] just because of the amount of time it takes, and it does take a lot of mental energy for them to reimagine it. **So, I think two [Data Sketches per year] is solid, but the other things I plan to incorporate more frequently**."

-Teacher Interview

"Without a doubt, the VTS will be embedded [in grades] 7 through 12. It will continue to be a significant part of what I do. … The Data Sketches I will definitely continue to use with my middle school students trying to teach, connecting data. What I haven't experimented with, what I'd like to is **how do we take some local data sets and then put those together** … related to this same phenomenon, and then we overlay them and see if we see connections. So that's one thing I've been thinking about that I haven't done yet, was expanding on that."

-Teacher Interview

"Yeah, I'll definitely use the VTS... I love using art or to introduce a phenomena. We use NGSS, so there's a lot of phenomena-based science. And so, I think that's such a good way to start out a unit. … **The Data Sketches was just the most challenging**. It doesn't mean that I wouldn't use that part again**. It definitely needs the most practice for me, but I think it has a real use**, and I think it could be used even just as a singularity, not necessarily looking for patterns, but just again that representation. … But yeah, I think it's worth playing around with."

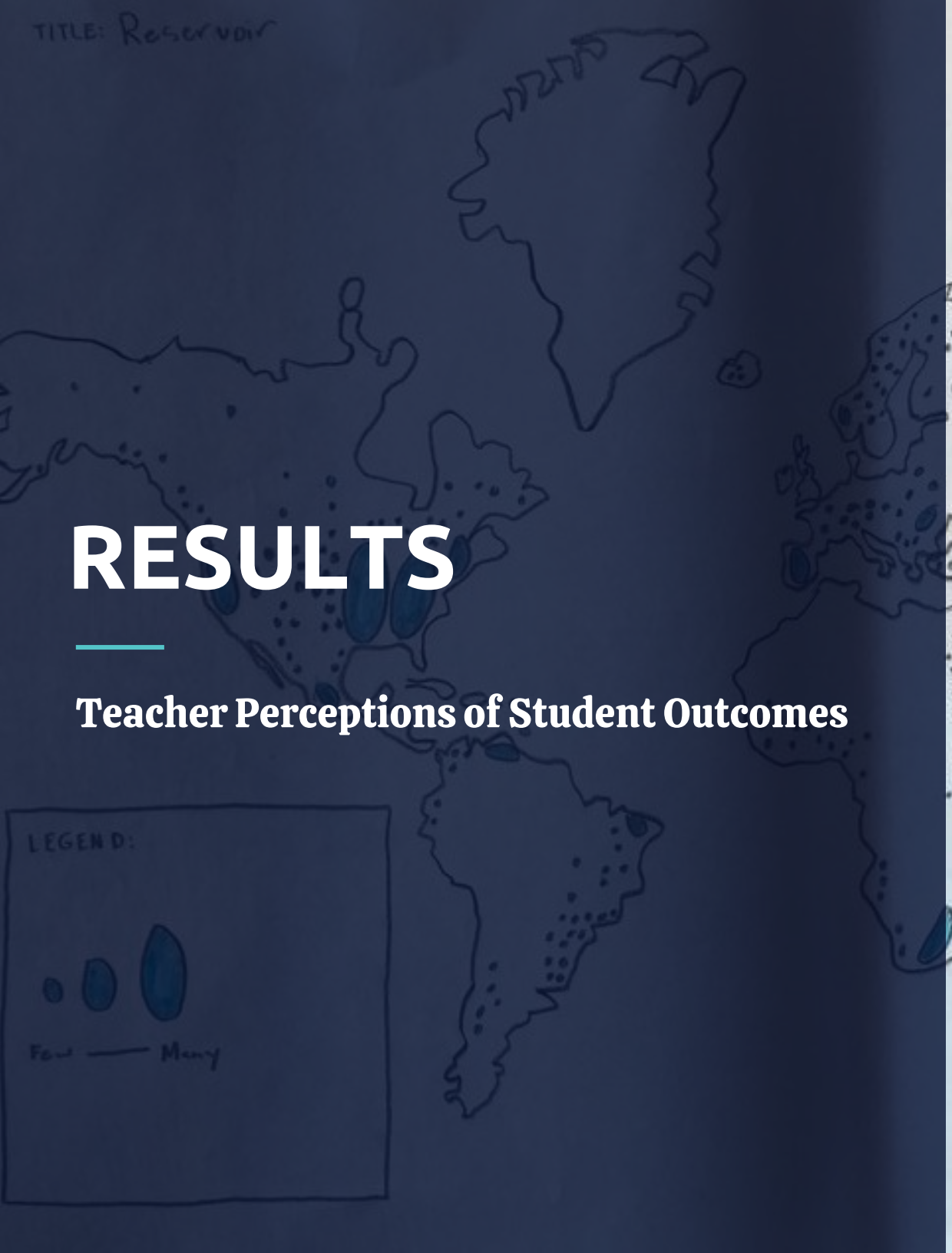
-Teacher Interview

"[I will use] Fenceposts for sure, for just a variety of things. I think it's a really good beginning of the year thing besides just 'getting to know you' things, but also just practicing collecting data and things I think fenceposts are really good for. I'll probably still try to incorporate some art and do little mini VTS art things at the start of units. … **I probably won't do Data Sketches as much, maybe once a year, twice a year sometimes seemed like a little bit much**, especially because a lot of them are like, we already did this."

-Teacher Interview

**"Well, obviously I'll keep using VTS. I mean, I'm sold on that.** I think I'm really eager to expand my use of that into just generally when we do something visual. So, I think with all my classes, I'd like to get started on training them in that process early in the year and then have it as just something I can pull out of my hat almost spontaneously. I like that."

-Teacher Interview




# RESULTS

## Teacher Perceptions of Student Outcomes

# Teachers' Observations of BIO's Impact

**Teachers felt BIO was most effective at helping students to build visual literacy and flexible thinking skills. They also agreed that it engaged a large portion of students, including those that don't typically enjoy science topics.**

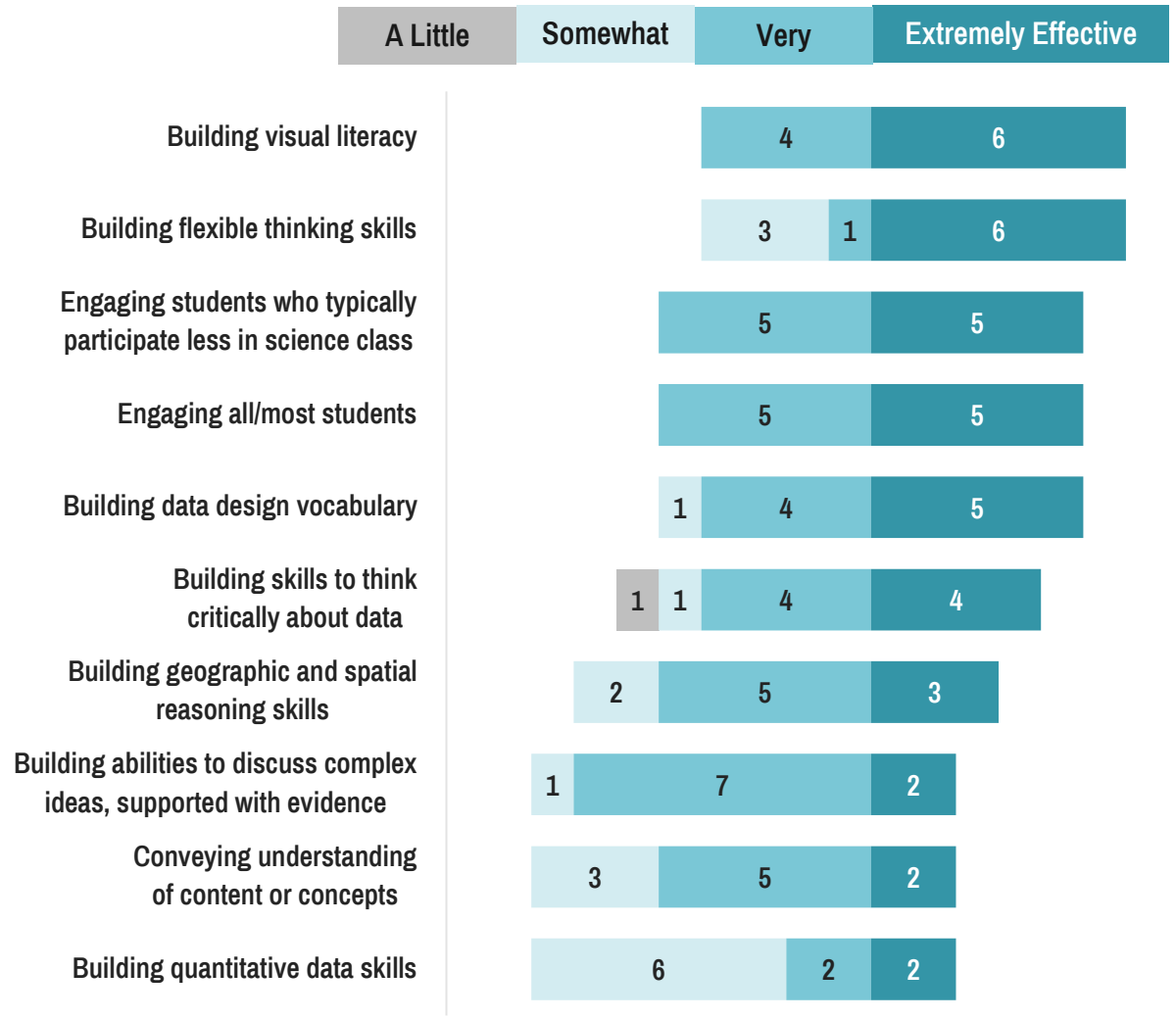
A majority of the teachers felt the BIO approach had been either 'very' or 'extremely' effective in supporting student learning in each skill type provided in the survey question, with one exception. Teachers did not feel it was particularly good at building quantitative data skills – which it was not designed to do. It is notable that a few teachers even found it useful in that regard. It also may point to some degree of desirability bias, with "somewhat" effective ratings being as negative as teachers were willing to go.

**BIO lessons seemed to excel at engaging students, encouraging flexible or divergent thinking, and developing visual literacy and design skills.**

Teachers felt the BIO lessons were less effective at more traditional math/science skills, such as quantitative skills, conveying content, and building abilities to discuss complex ideas with evidence.

**BIO's effectiveness in supporting areas of student learning.**

Teachers rated each area of student learning on a 5-point scale, with 1 being Not at all Effective and 5 being Extremely Effective. No teacher rated any statement as a 1 out of 5.



# Teachers' Reflections on Common Student Outcomes

**In interviews, nearly all teachers described several outcomes they attributed to the BIO lessons. Most commonly they saw higher participation, enthusiasm, and skills surrounding design and data.**

All but one teacher noted that BIO encouraged broader participation among students, general student enjoyment, or both**. The BIO lessons were very well-received by students and fostered participation from many who were not usually active in typical classroom activities.**

Beyond participation, teachers saw BIO building skills. They noticed students began to spend greater time looking closely at data, looking for patterns, and making connections – without the prompting of the activities.

Teachers also observed that students were deeply invested in creating strong visual products. Rather than a "whatever" attitude, students cared about choosing and coordinating symbology and making their work "pretty." This tied to teachers' noticing greater design skills among students, as well as insights into the challenges of visualizing data and communicating through visual representations.

### Changes in students described by teachers after doing BIO lessons

The numbers below indicate how many teachers touched on each theme at least once, either in their mid-point (Cohort 1 only) or post-PD interviews (Cohorts 1 and 2).

| | (n=10) | Student Outcomes During/After BIO Lessons |
|---|---|---|
|  | 9 | **Broad student participation**<br>Students that would not typically participate were active and engaged during BIO lessons; a wide range of students freely participated. |
|  | 8 | **Positive reactions from students**<br>Teachers reported general student enthusiasm and enjoyment during BIO lessons. |
|  | 8 | **Ability to recognize patterns and solve problems with data**<br>BIO lessons helped students to look closely at data without prompting, fully comprehend data visualizations, look for patterns, make connections, and/or solve problems using data or visual information. |
|  | 7 | **Investment in creating high-quality art products**<br>Students spent considerable time and energy working on or perfecting their designs or artwork, felt pride in their work, and/or requested to take it home to finish outside of class. |
|  | 7 | **Design skills and insights into data visualization**<br>BIO lessons helped students to better understand design concepts and the choices that go into making effective data visualizations and/or helped them think more critically about design choices in data representations. |

# Teacher Reflections: Common Student Outcomes

"One class I have with a lot of reluctant kids… I think even with that group, there's been generally more willingness to participate. With the other two classes, I think it's been pretty clear they are actually willing to participate more. I'm able to get almost everybody in the class to participate if I gave them time. … **But I think generally they're more eager to participate and I think I'm seeing more flexibility in their thinking**. Like, 'Oh, maybe it's showing this, maybe it's showing this'. Because I think hopefully, I've shown them that this is a brainstorming process where we're just trying to make sense of it and any idea is fine."

-Teacher Interview

"**I think generally the kids really liked the Data Sketches.** I think it was a popular activity, particularly the second time we did it. They realized after the first time, 'Oh, I made some bad choices,' but the kids who were very artistic I think really enjoyed that one. We did the Fenceposts, they loved the, 'Let's try to vote, let's lobby for the design tool that we want to use.' And there was some really fun creative thinking there. So, kids who are competitive kind of got into that because 'our idea wins,' that kind of thing."

-Teacher Interview

"And so, it became more natural I think, and they became better, and they were quicker to engage at quantifying the data and re-sorting [the Fenceposts]. And even without moving the cards, they could quickly, I mean, even when we ended up with three desks of cards laid across, they could go, 'Oh, well, there's a whole lot more green than there is red or yellow,' or whatever the answer was. And they could connect to what that meant. So, I did see that. **The graphing is getting better or the understanding of the data**."

-Teacher Interview

"The Data Sketches, that was their favorite thing. **Some of them were really invested in drawing the map perfectly but having that hands-on piece where it's still data but it also looks nice** and is pretty, I think it makes them more invested, and it gives them something to connect the data and their own experiences to."

-Teacher Interview

"I also think the Fenceposts and the Data Sketches, I think doing those, I think what that's really been helpful for is, like I said, **I feel like the kids are thinking more critically about the decisions that are being made when data is being presented that beforehand it was all just a mystery**. This must be the best way to present the data instead of thinking on a meta level about why people chose to present data that way. … I think the kids are becoming a little more critical about the data that they're looking at and they're actually looking at those things."

-Teacher Interview

# Additional Student Outcomes Observed

### Changes in students described by teachers after doing BIO lessons

The numbers below indicate how many teachers touched on each theme at least once, either in their mid-point (Cohort 1 only) or post-PD interviews (Cohorts 1 and 2).

| (n=10) | Student Outcomes During/After BIO Lessons |
|---|---|
| 6 | **Rich discussions and thoughtful interactions**<br>Students were able to engage in deeper or more detailed discussions than they would typically, including using visual evidence to support claims and make arguments. |
| 5 | **Greater or deeper content knowledge**<br>BIO lessons effectively communicated relevant content or concept understanding among students. |
| 4 | **Interpersonal skills and respectful disagreement**<br>BIO lessons helped students relate to one another, work together or collaborate efficiently, and/or provided norms for respectful disagreement during class discussions and group work. |
| 4 | **Flexibility and generating multiple possibilities with art or data**<br>Students were able to let go of the "right answer," come up with multiple possibilities or answers to a question, embrace ambiguity, and/or became more flexible in their thinking. |
| 2 | **Other student outcomes**<br>Other student outcomes included forcing students outside of their comfort zone with arts-based activities and time management skills while working on Data Sketches. |

**Other skill outcomes that were common across participating teachers included richer and evidence-based discussions, content acquisition, and comfort with ambiguity during and after BIO lessons.**

Each piece of the BIO process emphasized group discussion. From VTS-style discussions and following Fenceposts and Data Sketches, BIO pushed students to look closely and talk extensively about data and patterns. Teachers saw the benefits of this as students were engaged in deeper or more detailed group conversations, often starting to cite visual evidence when making claims or hypotheses.

**These discussions and the group work also led to students improving their interpersonal skills, learning how to collaborate and show respectful disagreement.** Friendly disagreement was expected, as students generated multiple possibilities (rather than one correct answer). In addition to social skills, teachers saw students show more flexible thinking and greater comfort in the ambiguity – an inherent feature of large, complex data. Finally, students also took away key science content and geographic awareness that related to teachers' curricular goals for the unit.

# Their Words: Additional Student Outcomes

"They really like the VTS discussion. Now they have started going, "I want to hear what so-and-so has to say." … They've taken that part where they're like, "I agree with so-and-so," or "I like what they said. They said this but I want to add on to this." And so**, I think it's made our class discussions better in general, and they participated more during all those VTS discussions than any normal class discussion we had**."

-Teacher Interview

"So, … before [my weather and climate unit] was a disaster. It was just an unmitigated disaster. We had the textbook and that's it. And the textbook just sucks at explaining things. So, they were just completely lost. I felt like I basically had to hold each of my 160 kids' hands through the project. And then at the end they were just still kind of like, "I don't know." And then this year they did it and they really do feel like they understand why Chihuahua Mexico has this climate and then why Venice, Italy has this climate. **They're arguing really well about what factors lead to that. And part of it is that we did the maps, and they get to see all these different factors**."

-Teacher Interview

"But other kids will be like, now if it's a very open-ended, what you see, a lot of kids will raise their hand and say, 'Oh, I see this, and this is my guess.' **And it kind of takes the pressure off of them being right. And so, I think more kids want to participate** and it's something different too. It's not the same old stuff that they're used to."

-Teacher Interview

"But [the VTS-style discussions] also had them use more evidence in their responses because I think sometimes when we just go over answers to questions or whatever, they're like, "Oh, this is the right answer." But then **if we're having a class discussion and the norms are set, you can disagree with people or you can agree with people, but you have to tell me why**. I think that's way more valuable because they're pulling evidence from something."

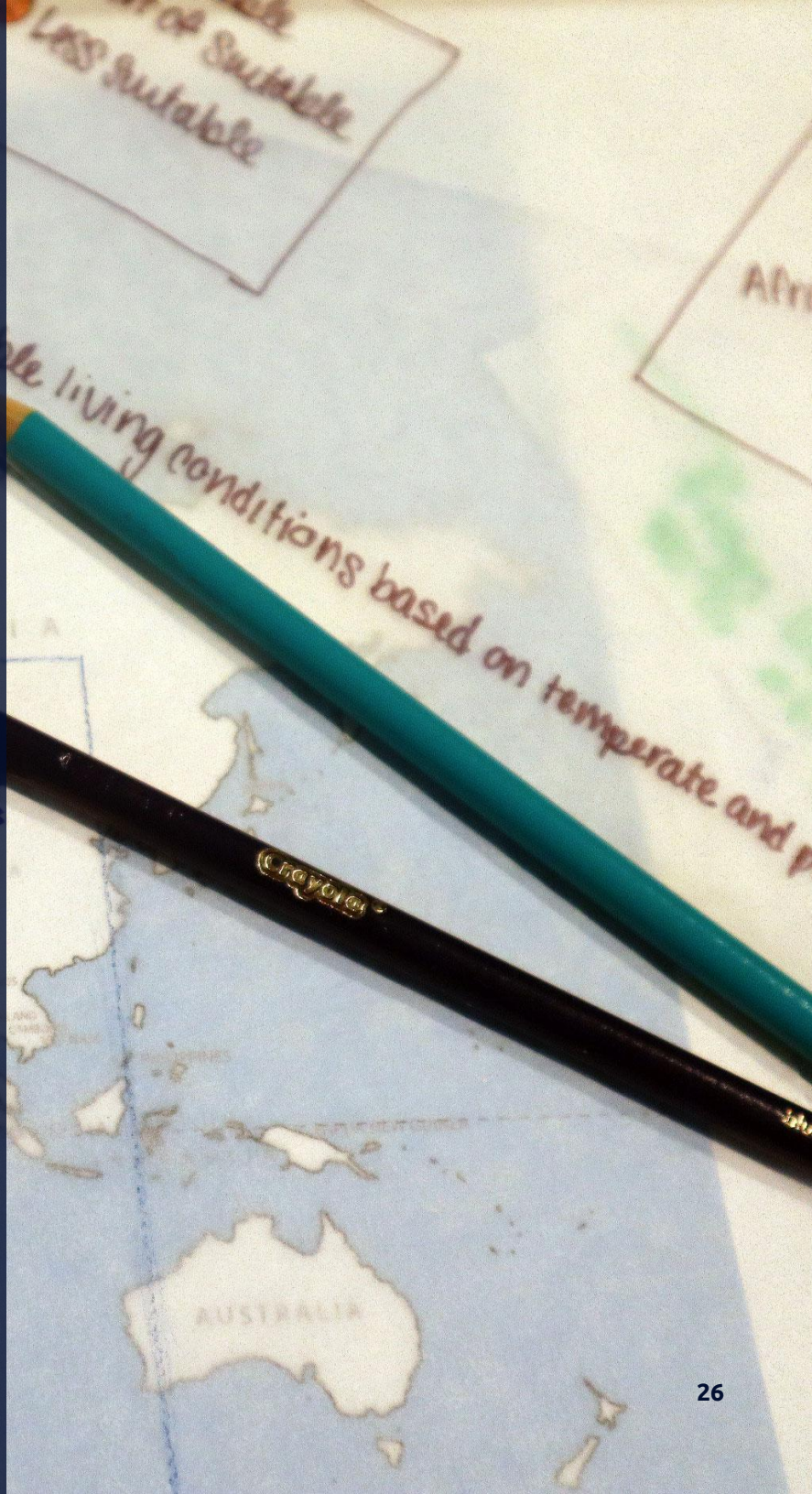
-Teacher Interview

"It was new for me in a lot of ways too. So, I'm working through it with the kids, and **I think it demonstrates that there's no correct one singular answer and there's a lot of interpretation and I'm doing it with them**. And even as I was finding the data and then we're looking for patterns. I think it just gave that opportunity of it is not black and white and there's a whole array of where we want to get to and how we're using that tool to find it. I think it was good for those kind of discussions. There's no singular correct answer that we were trying to find, so I think that really helped facilitate that."

-Teacher Interview

# RESULTS

## Student Feedback and Learning



# What Students Liked about BIO Lessons

**Students from Cohort 1 classes most often said they enjoyed Data Sketches. What students liked the most about all of the activities was making discoveries using data and being able to make creative design choices.**

In terms of what components students liked, the VTS-style discussions were identified by a quarter of students interviewed. Fenceposts were rarely mentioned by students as the most enjoyable element. Data Sketches was the most recent activity students had done, however interviewers described all BIO activities to jog memories.

More importantly, what they liked wasn't just "doing art is fun." **Students commonly described that they enjoyed the process of discovering new ideas or connections through the process, as well as being in the role of *making* design choices for a quality visual product**.

Other students enjoyed collaborating. This included group work and hearing from other students that noticed different details or came to different conclusions than them. Some students simply enjoyed drawing, felt calm, or had other positive reactions.

### How students described what they liked about the BIO lessons they experienced

Coded, open-ended responses to a student interview question asking what students liked about BIO lessons. The n reflects students that were asked and provided a response to each question and/or sub-question. Students could name more than one activity or reason, so percentages add up to more than 100%.

| Which BIO Lesson(s) Students Recalled Liking | (n=67) |
|---|---|
| **Data Sketches** | **60%** |
| **VTS-Style Discussions** (Art or Data) | **25%** |
| **Fenceposts** | **4%** |
| **Other** (Unclear or non-BIO activity; not coded below) | **15%** |

| What Students Liked about the BIO Lessons | (n=60) |
|---|---|
| Making **observations**, **discovering** new **connections**, and **meaning-making** | **40%** |
| Making **design choices**, exercising **creativity**, creating a **quality** product | **32%** |
| **Collaborating** or **connecting** with others; hearing **others' viewpoints** | **23%** |
| **Drawing** or using their **artistic skill** | **12%** |
| Feeling **relaxed** or **calm** | **8%** |
| General **positive** (fun, cool, different) | **7%** |

# What Students Disliked about BIO Lessons

**What students disliked about BIO lessons.**

Coded, open-ended responses to a student interview question asking what students disliked about BIO lessons. The n reflects students that were asked the question and chose to respond with one or more dislikes. Students could name more than one activity or reason, so percentages add up to more than 100%.

| What Students Disliked about the BIO Lessons | (n=70) |
|---|---|
| **None: Couldn't think of any dislikes** about BIO lessons | 43% |
| **Tracing the continents** was tedious or difficult | 10% |
| Challenges with **design** or **choosing appropriate symbols** | 10% |
| Running **low on time** or **feeling rushed** | 9% |
| **Materials issues** (tracing paper doesn't line up, map proportions) | 6% |
| General **confusion** about activities | 6% |
| Feelings of **boredom** | 3% |
| Challenges with **group work** | 3% |
| **Other** student challenges | 11% |

**Nearly half of interviewed students couldn't think of anything they disliked about BIO. Of those who could think of something, some struggled with elements of Data Sketches, such as tracing continents and feeling rushed.**

Nearly all of the challenges named by students seemed to relate to the Data Sketches versus the other BIO elements. These dislikes largely mirrored challenges described by teachers in classroom and time management during BIO lessons, given the detailed work in this element.

Some students spent too much time tracing the continents or felt the tracing was tedious. A few felt they struggled to choose symbology or failed to communicate with their group about symbols that would layer effectively in the final product. Others had materials issues, most often with the tracing paper shifting as they drew.

A smaller number of students reported general confusion, feeling bored, and other miscellaneous challenges such as finishing before the rest of their group, struggling with ambiguity (wanting to have a single "right" answer), and not enjoying drawing or writing.

# What Students Learned from BIO Activities

**Almost 60% of interviewed students were able to recall something specific they had learned about data or maps in a BIO classroom. This included science information, thinking analytically, and awareness about data and visualization.**

Over a quarter of students (28%) recalled learning new science information or a surprising fact through exploring geospatial data visualizations in the various BIO activities. 13% described how they learned that there isn't always a single right answer or otherwise described using flexible or analytical thinking about complex data or phenomena.

Other students commented on discovering how many different types of data were available, and how mapped data could be useful in a number of ways. Others learned about making purposeful design choices or how data representations are made. And finally, some reported learning the fundamental components of data visualizations, such as using keys and legends.

Around 40% of students weren't able to recall anything in particular that they had learned about maps or data that school year when directly asked.

**What students recalled learning from BIO lessons.**

Coded, open-ended responses to a student interview question asking what students recalled learning that semester about data and maps. The n reflects students that were asked the question and chose to respond.

| (n=69) | What Students Learned from the BIO Lessons |
|---|---|
| 59% | Students that **could recall something they learned** from BIO |
| 28% | Discovered **new science information** through mapped images and/or data |
| 13% | Comfort with **having no "right" answer,** thinking analytically about data |
| 9% | Understood the **wide range of geospatial data** and how it **could be used** |
| 9% | Insights about **design choices** and **representation of data** |
| 9% | Improved understanding of **data representation elements** such as keys |
| 41% | Students that **couldn't recall anything** they had learned |

# Students' Words: BIO Experiences and Learning

"One thing that I learned was one data set that [Teacher] assigned us was, I think it was the wildfires, the amount of wildfires around the world and increase. And so, then we connected that data set to maybe the amount of droughts that happened this year. If there was an increase or decrease in droughts, then maybe that affected the wildfires because if there was a lot of droughts, then maybe things like the air would get very dry and it would make a bit easier for wild forests to catch on fire and create more wildfires."

-Student Interview

"I liked the color matching part to where all the data was. … Oh, I think it was about population, so I used a light pink for areas that were low in population and a dark purple for areas that were dense in population. I found that really interesting, because I liked seeing where a lot of people were, basically. … It was kind of interesting to see that the bigger an area is doesn't necessarily mean that there's going to be more people there."

-Student Interview

"I think there was a lot of emphasis on being able to visualize this data in certain ways and communicate it to an audience. So, I think I practiced those skills this year a lot. I learned about the different methods for visualizing data… I learned, in respect to this sort of activity, I learned some about how some data was collected, specifically when it tied in with [topics from] the rest of the class."

-Student Interview

"I really liked the teamwork aspect of it because all of your maps had to correlate, and especially with the keys, if everyone wrote their symbol at the very top of the key box, then all of them would overlap, so you just ... It really helps with communication because you have to know what everyone else is doing, so that way it all confines to a visible map. … It makes it easier to understand when you have multiple opinions on it, and so when you're working together as a team, you can make sure that the symbols that you're using represent the math that you're describing, and so that way it's easier to understand..."

-Student Interview

"[Teacher] said, "Oh, let's do a different way of teaching." [So, for] a few days, he shows us a diagram, and everyone gets up and they say like, "Oh, what do you think this is about? What do you think this is about?" And you have to use all the information around it and just figure it out, which I found that really fun and entertaining how we could just disprove each other's arguments because of more stuff in the picture. So, I found that fun."

-Student Interview

# CONCLUSIONS

## Classroom Implementation of BIO


# Conclusions

## >> Classroom Implementation

Even in a semi-controlled PD project, where teachers were asked to try all parts of the framework, participants in the Building Insights through Observations project varied substantially in the details of how they implemented lessons. This suggested they were able to adapt enough to find its "fit" in their classroom. Moreover, all teachers reported they would keep using BIO lessons moving forward.

Overall, teachers felt that the discussions following each BIO lesson were critical for supporting students' processing and takeaways. It helped them emphasize pattern-finding *and* the targeted science content alike. Similarly, time spent choosing design elements and symbols tended to pay dividends in student comprehension and buy-in. This was reflected in students' reported learning, as well.



### 1 Highly Adaptable Lessons

The VTS-Inspired Discussions and Fenceposts components were viewed as broadly adaptable and most likely to keep being used beyond the BIO project. Teachers seemed to value the ease of both these activities, finding them to be applicable to a broader range of teaching circumstances and topics and low time commitment. In addition, VTS could be incorporated "on the fly" to prompt student thinking or to assess prior knowledge.

### 2 High Investment, High Reward

Data Sketches took more materials, prep, and class time, compared to the other two activities. Some teachers were less certain that they'd continue doing the full activity as originally conceived, largely due to time barriers. However, student data suggested that this activity made the biggest impression on students, who seemed to take away complex ideas about the interplay of phenomena and understanding of geospatial data. A greater understanding of exactly what about this lengthy activity sparks this thinking would be useful to guide future teachers in adaptation choices.

### 3 Learning from Close Observation and Discussion

Teachers' reflections suggested that the emphasis on close observation and discussion of data were critical features to maintain. Teachers described the richness of BIO-generated discussions, as well as increased student ability to interpret data patterns and think critically about design choices in data representations. Students' reflections on their learning reflected the same themes, as they discovered new insights and thought more deeply about data and design.

# Considerations for Future Research

## Deep Dive into Data Sketches

A somewhat contradictory finding emerged in the data between teachers and their students. While teachers were least likely to keep using the Data Sketches activity, students tended to report it was the most enjoyable part – and largely because of the knowledge and skills they developed. In contrast to the VTS method, which has been extensively studied already, Data Sketches was developed for this project. The exact ways in which students interact with the lessons and learn through the process would benefit from further study, given the promising results.

## How Important is Fidelity?

A strength of the BIO approach was that teachers adapted its core elements to suit their needs and instincts about their classrooms. However, they were required to try all of the pieces twice per year. A question that remains is how much of the BIO "magic" (in terms of student outcomes and behaviors) is dependent on the completion of: (1) all three components; (2) in full; (3) in sequence; and/or (4) multiple times per year. Conversely, it could be valuable to understand each piece as a strategy in isolation to advise teachers on what each piece, uniquely, adds to student learning.

## Varied Discussion-Based Gains

The evidence points to the critical role played by frequent discussion in BIO. It seemed to be a key mechanism by which students build skills – looking closely, identifying patterns, thinking about design choices, supporting ideas with evidence, getting comfortable with ambiguity and multiple interpretations, and even social-emotional skills of interacting with peers. The last item was an unexpected outcome, but is a promising area to explore further, as fostering respectful discussion and debate of ideas is a key skill of science that can be difficult to find ways to scaffold in today's classroom contexts.

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