Shifts in Teacher Attitudes and Values after Arts Integration PD

Research Brief

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

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 question. 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

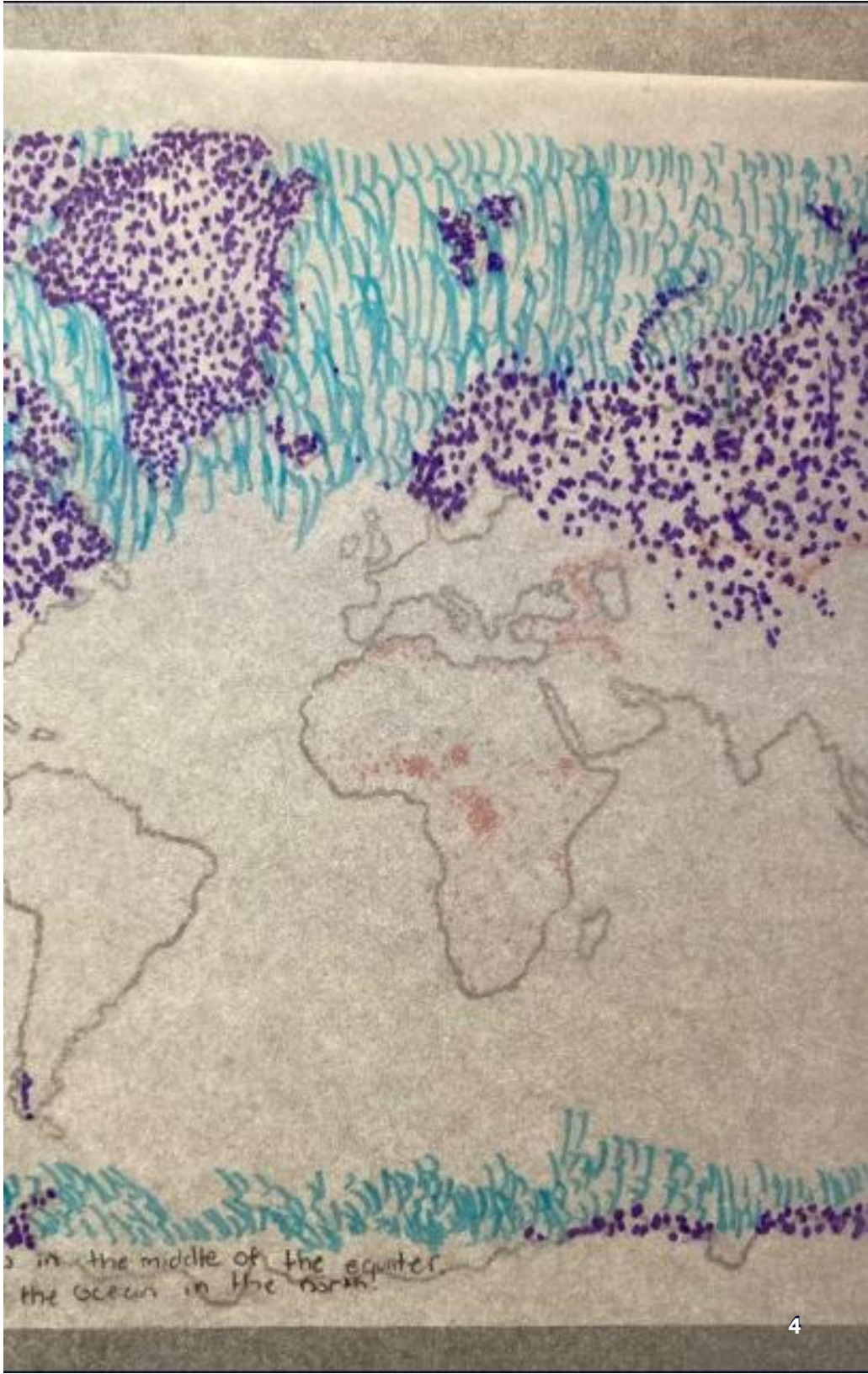
RQ3: In what ways do science teachers develop their professional knowledge and practice, particularly around geospatial data visualization content and pedagogy?

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?

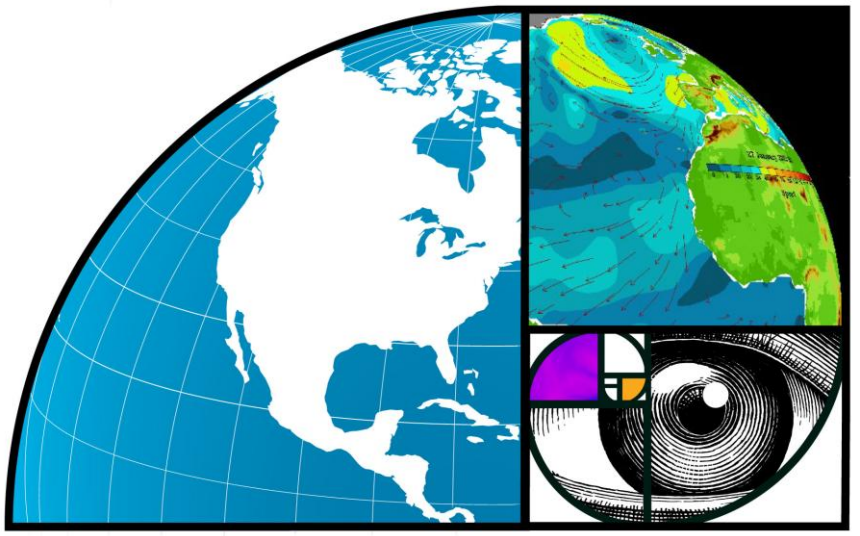


BIO Project Overview

This Research Brief focuses on change in teachers' attitudes, values, and practices regarding teaching with data and arts-based approaches following the completion of BIO professional development and implementation of BIO lessons in their classrooms.

The Building Insights through Observation (BIO) project was implemented in partnership with 10 middle school science teachers from around the U.S. Teachers were in 2 cohorts, participating from 2022 to 2024. The timeline of PD experiences within BIO were as follows:

- **Summer PD 2022**: Cohort 1 initial 3-day Workshop (Easton, PA)
- **2022-23 School Year Implementation**: Cohort 1 members create and implement 2 lesson plans per teacher; Project team provides coaching, advice, and technical support throughout lesson development and implementation; teachers submit reflections after each implementation
- **Summer PD 2023**: Cohort 2 & Cohort 1 at 3-day Workshop (Easton)
- **2023-24 School Year Implementation**: Both Cohorts' members create and implement 2 lesson plans per teacher; Project team provides coaching, advice, and technical support throughout lesson development and implementation; teachers submit reflections after each implementation
- **Summer PD 2024**: Culminating workshop to reflect on critical elements of the curricular model, PD, and developing resources for teachers fieldwide



Research Question 3:

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

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)*

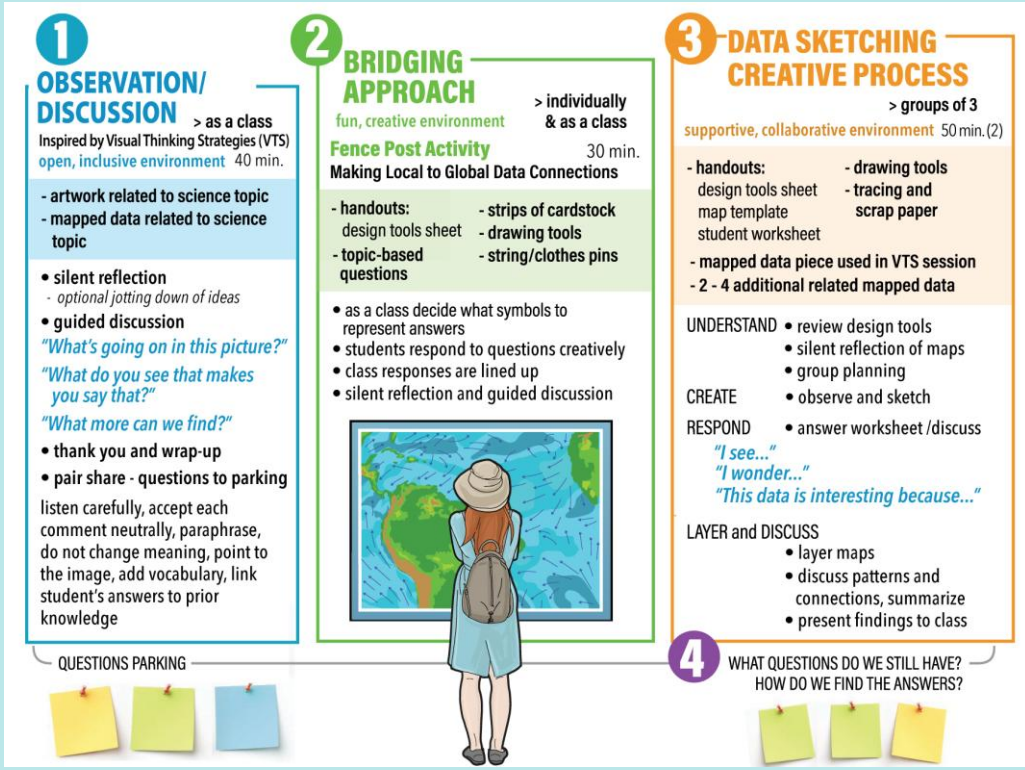
As a class, teachers guide students through a carefully facilitated discussion, first about a piece of artwork and then about a data visualization, using the VTS technique. Discussions are open-ended, generating interpretations and observed evidence to support them.

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.

BACKGROUND

Research Methods: Investigating Change in Teachers

Data Sources: 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, starting with a baseline (pre) prior to starting the PD. 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 attitudinal shifts and values, the pre-survey and final post-surveys asked teachers to reflect on their classroom practices with data and art, as well as their values, priorities, barriers, and confidence in teaching with art and data. Interviews explored their shifts in attitude and changes to their teaching practice in greater depth.

Data Analysis

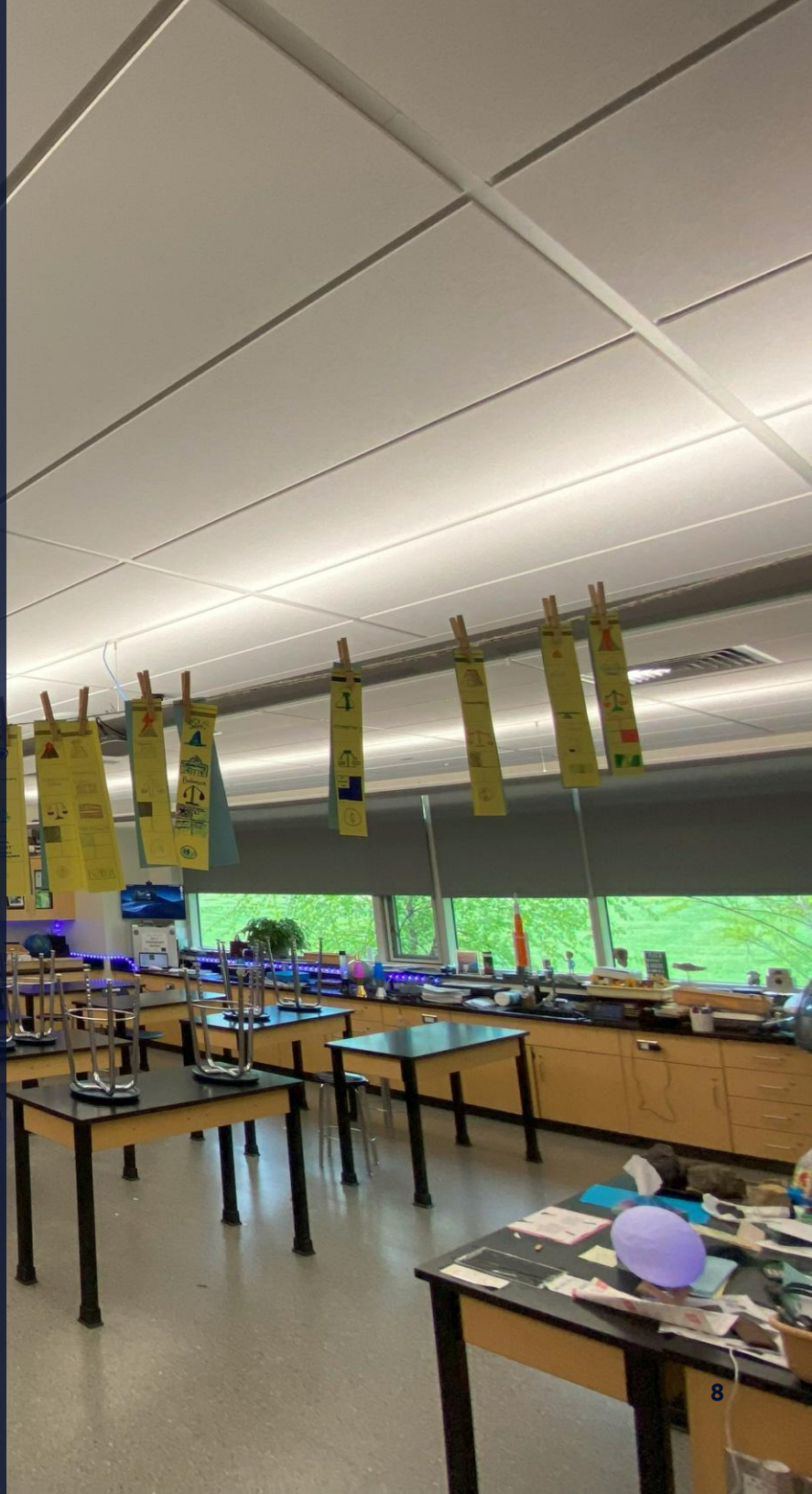
Survey data were analyzed descriptively, exploring the frequencies of ratings by the 10 teachers in the final survey of the project. All interview data were analyzed using a general inductive approach.

Preliminary coding of qualitative data occurred throughout the project to inform the curriculum team in refining 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 received from participants and team members. All transcripts were reviewed and recoded, using this new framework. This report presents results of this final analysis of data.

RESULTS

Arts-Based Practices and Value



What Teachers Value about Arts-Based Practices

Teachers' pre- and post-PD interviews reflected broader and deeper values of what arts-based practices can bring to science education. Post-BIO, teachers were more likely to describe the arts as creating access to science, building observational skills, and driving understanding of data design.

After BIO PD, nearly all teachers described arts-based practices as valuable to help their "non-science-y" kids feel successful, which was double the number who mentioned this idea pre-PD.

Some of the greatest growth was in the skill gains that the arts could promote. While many teachers described students doing scientific illustrations prior to BIO, only two teachers thought those tactics promoted observational skills. After BIO use, 7 of the teachers talked about the value of arts for this skill gain. Similarly, the potential for the arts to aid with data understanding was only on the radar of 1 teacher pre-PD; but by the end, over half of teachers brought it up as a valuable addition.

One other shift in perceived value was seeing the arts as a way to demonstrate understanding, but this was a smaller shift, comparatively.

What teachers valued about arts-based practices and how they changed in frequency before and after the BIO PD.

The numbers below indicate how many teachers touched on each theme at least once in their pre-PD interview, and/or in post-PD interviews (occurring after PD 1 and/or PD 2, depending on cohort).

I believe arts-based practices help students...

	Pre	Post-BIO	(n=10)
⌃⌃	4	8	**Access new ways to do science** Arts help students feel successful in science who might not otherwise, or to see opportunities to use the arts within science work or processes.
⌃⌃	2	7	**Build skills of close observation** Visual arts can help students to get into the habit of looking at or examining things closely to notice details and make meaning.
⌃⌃	1	6	**Visualize data and make design choices** Arts-based practices enable students to think more deeply about data, patterns, visualization, and design choices, and the design decisions necessary to communicate data to others.
⌃	3	5	**Demonstrate deeper understanding** The arts allow students to express complex understanding of a topic or concept; or help students to apply and express understanding of science concepts better than a traditional test or exam.

Their Words: Value of Arts-Based Practices Post-PD

"Creating art for them I think is really cool. We've done comic strips and stuff, but the data sketches was cool. They all wanted to trace and draw and stuff, **and I think it's important for them to realize that art can be a part of science and some people's jobs are doing art for science**, all of those anatomical diagrams and stuff, that's art and that's science."

-Teacher Interview, Post PD 2

"So, for them to be in the driver's seat [during VTS with Art], **you get to see what they know. You get a glimpse into their prior knowledge.** You're giving everybody a common language also, because we're all starting at the same place, and as you're going through it, everybody's calling it the same thing. And then you can sneak in, 'Oh, do you mean this?' 'Oh yeah, yeah'. Oh, but now they know what that is, right? … **We are assessing our kids' knowledge as it goes**."

-Teacher Interview, Post PD 1

"So, **the art is some of the only time that they're chill, that they're slowing down, that they're seeing details and stuff, so the value of that is instrumental**. And naturalists, that's why they teach naturalists to sketch things in the field because you're forced to continue to look back and forth, structure and function. That's another cross-cutting concept in science, looking at how the shape of things might affect their function. So, I see a lot of value in it."

-Teacher Interview, Post PD 1

"The design tools piece, **really opening up the hood of these data sets and thinking about, hey, whoever created this had to go through a decision-making process, and let's practice that ourselves. I think that's really powerful for kids to realize**. Any kind of media that they see has to go through a design process, and there are decisions that are made and that helps bias the story that you're trying to convey. And I think that's really helpful for kids to see that.

-Teacher Interview, Post PD 1

Other Values of Arts-Based Practices

Other, less common themes, in what teachers valued about arts-based practices and how they changed in frequency before and after the BIO PD.

The numbers below indicate how many teachers touched on each theme at least once in their pre-PD interview, and/or in post-PD interviews (occurring after PD 1 and/or PD 2, depending on cohort).

I believe arts-based practices help students...

	Pre	Post-BIO	(n=10)
⌃⌃	0	4	**Think about more or different viewpoints** The arts helps students to embrace divergent or creative thinking or consider viewpoints different from their own.
⌃	1	4	**Use art as an entryway to science** Arts help students build interest in science topics or create an accessible starting point to approach science.
⌄	3	2	**Visualize processes and phenomena** Arts-based practices allow students to visualize and/or conceptualize phenomena, scientific processes, or patterns.
⌃	1	3	**Other valuable elements** The arts help kids focus, create down time in class for busy teachers, and allow students to cope with emotionally challenging science topics, such as climate change.

Values of the arts that were described by teachers less often, but also increased after BIO PD, included the value of arts for building interest in science and encouraging divergent thinking. Notably, teachers describing the value of the arts to illustrate phenomena decreased a bit.

A massive area of change in value of the arts centered on how it aided divergent thinking. Four teachers felt the arts were valuable to help their students consider different viewpoints or get more flexible in their thinking; this was not mentioned in any way prior to the professional development.

After BIO PD, nearly half of teachers felt the arts were valuable as a catalyst for students' interest in science topics. This shift from pre-interviews may reflect how BIO introduced the idea of using art-based practices early in a unit, rather than using it solely as a wrap-up to demonstrate understanding (as most teachers were doing pre-BIO).

The only theme that decreased after BIO PD was the value of the arts to visualize processes and phenomena. This shift seems to reflect how BIO broadened their view away from arts being a tactic primarily for illustration and diagramming.

Their Words: Other Value of the Arts

"I've really tried to, and my situation's unique in where I teach and getting away from spoon-feeding people into one right answer and so forth. This process has helped with that in a sense that **it slows students down to listen better, to hear other viewpoints, to reconsider the conclusions they came to based on the data they looked at, other people seeing that data in a different way**, I definitely have seen value in that."

-Teacher Interview, Post PD 1

"[I used to think] the art is not as important as the data or the science knowledge behind it, but I think my perspective has kind of changed. So, **art is a good entryway into all of the deeper science things because there's deep science to be found in art pieces and it's a good introductory thing to at least spark interest**. And I think that's valuable in and of itself because maybe you really don't care about the math behind something, but the art interests you. And so, then you do start to get curious about the art and the math and stuff."

-Teacher Interview, Post PD 2

"Specifically, just speaking to the VTS first is 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 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, Post PD 2

"[If] we're talking about abstract phenomena, let's say, molecular motion, right? I don't really know what's in your head. I know what's in my head about [how] molecules move. Right? And no one's ever seen... You can't take a photograph of a water molecule because they're too small. So, we have models. And so, what's the model in your head? What do you think is going on? And so, **using arts-based practices to illustrate your thinking, I think is a really, really powerful way to get inside kids' heads**."

-Teacher Interview, Pre PD

"I think **having an art piece makes them invested in it and it also helps them start building connections with what they know** versus the piece of art, and then they can start drawing on that for the actual data."

-Teacher Interview, Post PD 1

Changes in Teachers' Values of Arts-Based Practices

Individual teachers showed changes in their valuing of the arts in many ways due to BIO PD. This included its value for helping students make detailed observations, visualize design choices, and access new ways of doing science.

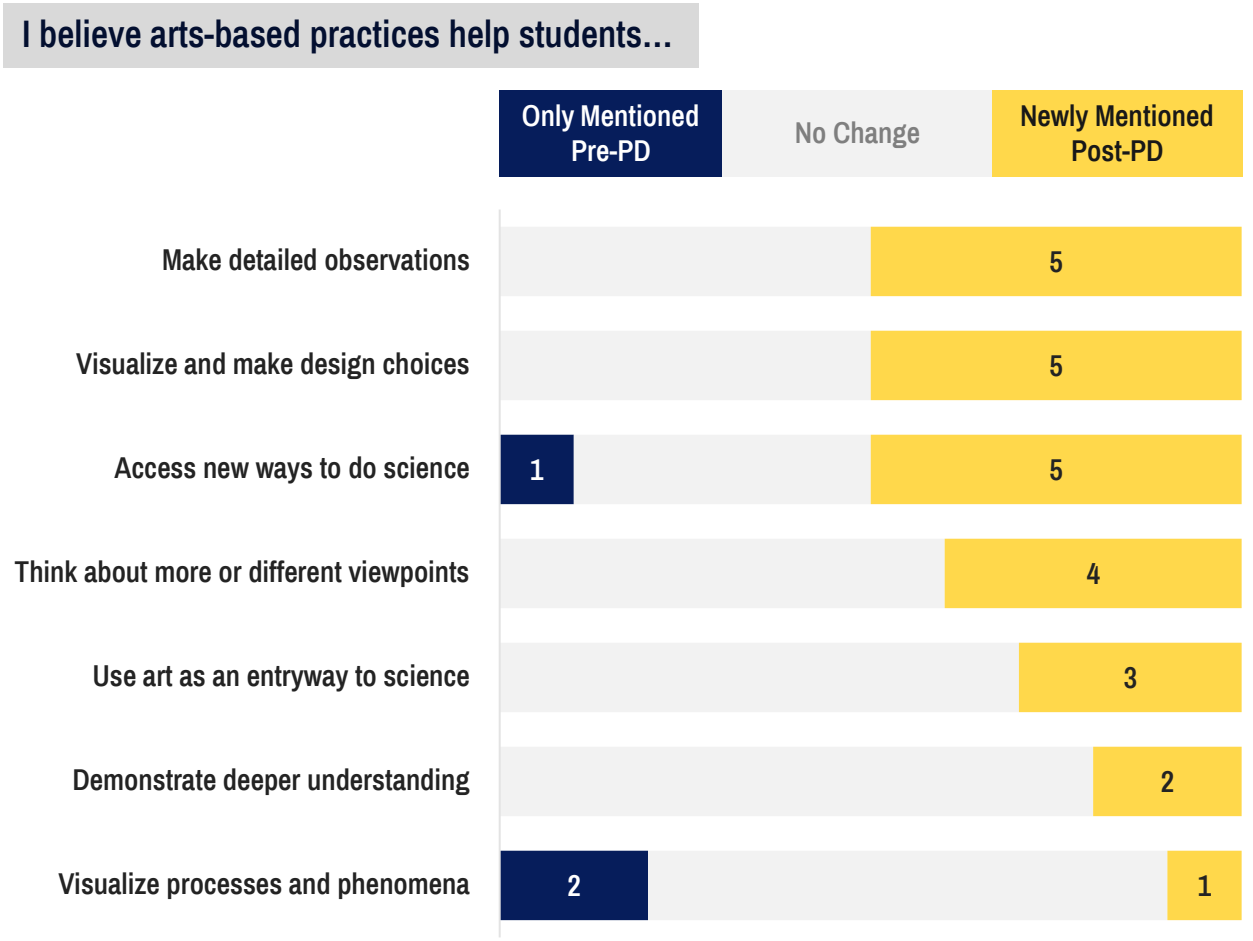
Overall, **teachers were able to describe their value of arts-based practices in many new and more diverse ways after completing the BIO PD**, and all generally indicated that their valuation of the arts had increased due to the project.

Aspects of arts-based practices that were valued at the beginning of the project (see prior pages) were typically repeated post-PD, with more teachers joining them in stating those values.

Teachers tended to expand their thinking about the value of arts considerably. Pre-BIO, teachers named 1.5 themes about the value of the arts, on average. **After completing the BIO PD, teachers brought up 3.9 distinct themes about the value of the arts – an increase of 2.4 themes.** Cohort 1, who had 2 years of PD, was even more expansive in their thinking, with members each raising (on average) 4.2 distinct themes; with Cohort 1 raising 3.2 themes per teacher.

How individual teachers' descriptions of the value of arts-based practices in science teaching changed after BIO PD.

Data are from coded, semi-structured interview responses. The numbers below reflect changes in each individual teachers' ideas. Yellow bars show the count of teachers for whom an idea was **newly expressed Post-PD.** Blue bars indicate how many teachers raised an idea pre-PD, but didn't repeat it by their post-PD interview. **Teachers that repeated a theme in both interviews or did not bring it up at all are represented in the central grey bar.**



Classroom Arts-Based Practices before BIO PD

All but one teacher was already using some arts-based practices in class before starting BIO. All of these teachers used drawing to illustrate or model concepts, with some describing other activities that used art to communicate.

All teachers who used arts-based practices pre-BIO described a range of modeling, diagramming, and illustration tactics. This included paper mâché planets, drawing 2D models on paper or white boards, diagraming processes, and illustrating (and labeling) plants or other objects.

Most teachers described at least one other activity that involved design or drawing. These activities most often included engineering projects with a decorative component or conceptual art in which student had to envision and draw something to align with a scientific concept (e.g., a flower suitable for a specific pollinator).

Nearly all arts use seemed to be considered an add-on, where art was in service of traditional ways of teaching and learning science concepts. While students were required to draw or create, it was usually toward a correct answer or single right way to draw what was required of them.

Ways teachers included arts-based practices prior to starting BIO PD.

The numbers below indicate how many teachers touched on each theme at least once in their pre-PD interview.

(n=10)	Classroom Arts Practices Before BIO PD
9	**Modeling and Scientific Illustration** Activities that involved students drawing out visual models or making scientific illustrations
7	**Art-Science Activities** All other science-art activities that did not involve modeling or illustrating; subcategories below
3	**Design in Engineering** Applying design or aesthetics within an engineering process or challenge
3	**Apply a Concept via Creative Product** Activities that use a drawing element or other creative product to apply or demonstrate a scientific concept (genetics, pollination, etc.)
1	**Depict What was Learned through Art** Art as a method of reflecting on content learned in class
1	No arts-based practices in the classroom prior to BIO PD

"I guess we do some cell diagramming, but that's drawing what we tell you to draw."
-Teacher Interview

"I am really a big fan of having them draw models of different things with labels ... like a before and after just trying to solidify what actually happened in our lab. And I think drawing, that was a really good way to do that."
-Teacher Interview

Frequency of Arts-Based Practices due to BIO

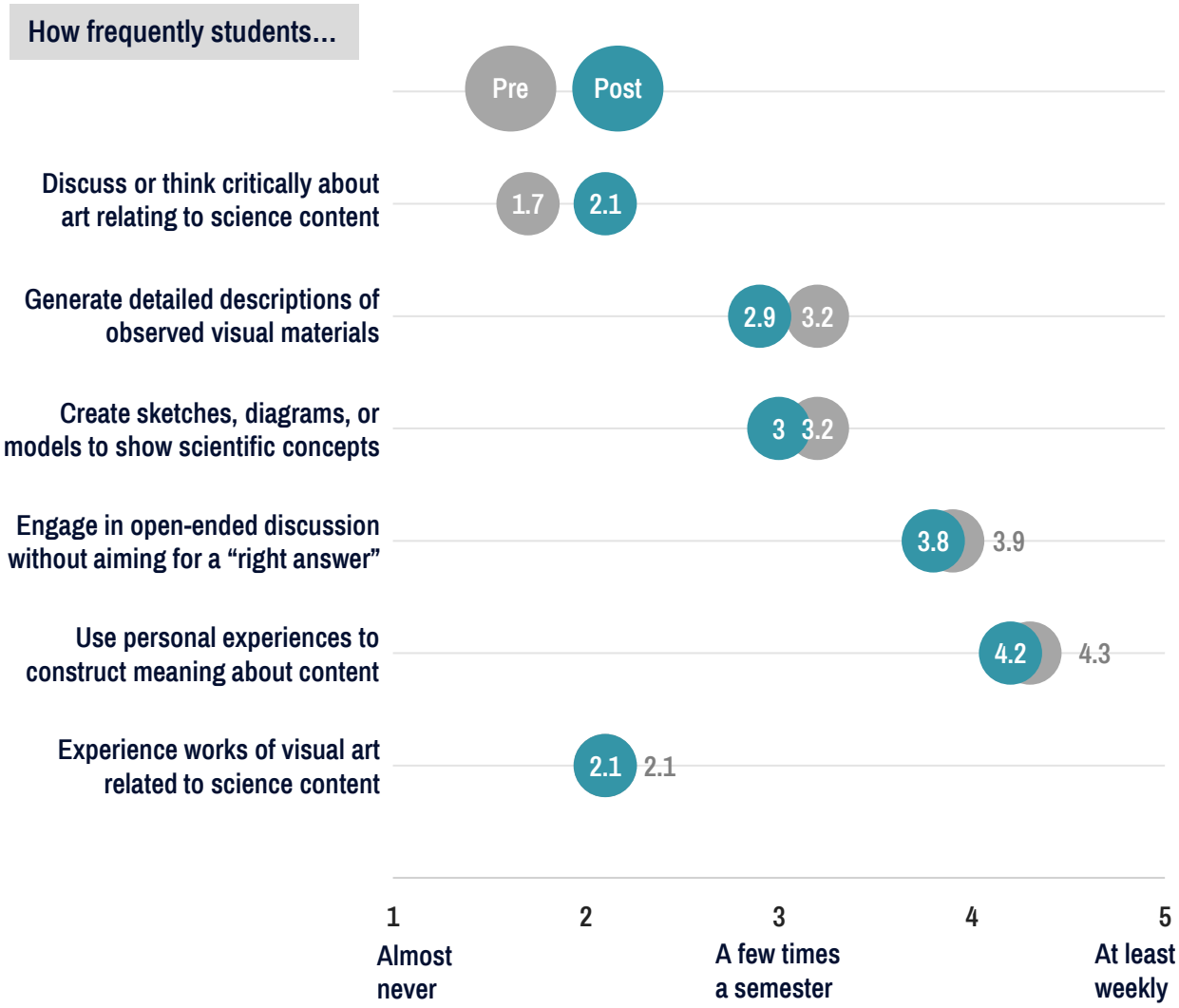
Teachers' reported frequency of using specific arts-based practices did not meaningfully change after participating in the BIO professional development.

While teachers reported a slight increase in frequency of discussing or thinking critically about works of art (an element that we know was a novel addition for teachers' practice), the change was minimal. On average, it shifted from being reported as something they "never" did, to something they did a couple of times a year (in the BIO lessons). Teachers reported the frequency of other practices stayed roughly the same before and after BIO.

While teachers did not feel they were doing these arts-based activities substantially more (or less) frequently during BIO, some teachers voiced intentions to try other arts-based practices after the BIO project wrapped up, when they would have more bandwidth to try new things beyond the prescribed BIO lessons. The qualitative data suggest that teachers were changing the ways in which they thought about and applied arts-based practices, rather than simply doing them more often.

Changes in reported frequency of using specific arts-based practices in the classroom before and after BIO.

Teachers rated each statement on a 5-point scale, with 1 being 'Never or almost never,' 2 being 'A few times a year,' 3 being 'A few times a semester,' 4 being 'At least monthly,' and 5 being 'At least weekly.'



Change in Confidence with Arts-Based Practices

Teachers showed greatly increased confidence in their ability to integrate and facilitate arts-based practices into their teaching after participating in BIO PD.

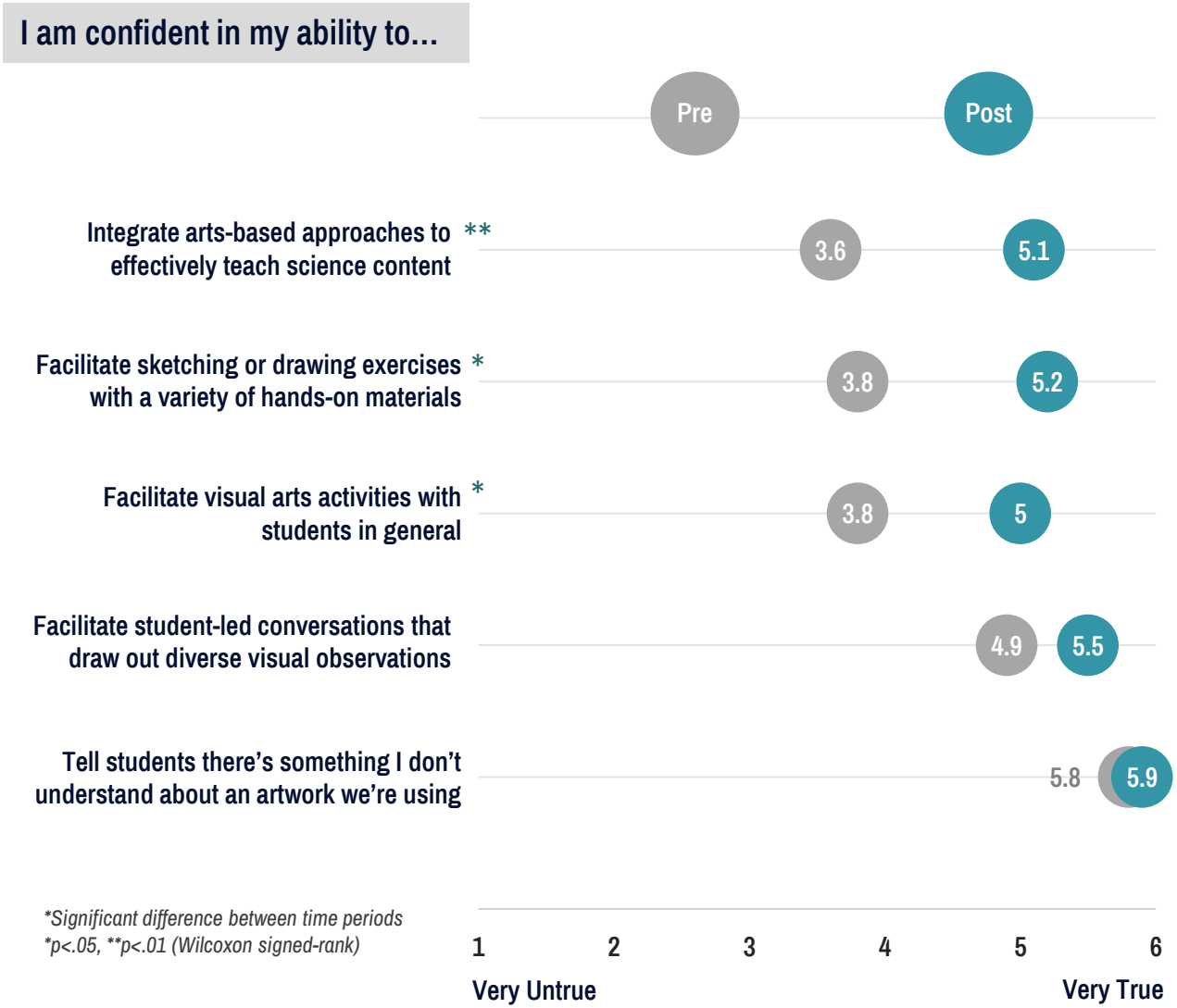
Teachers showed the greatest growth in confidence in their ability to implement three arts-based teaching practices – integrating arts-based approaches into science teaching, facilitating sketching or drawing exercises, and facilitating visual arts activities in general. Average ratings on these items showed teachers entered PD right at the midpoint between feeling unconfident and confident; by the end of BIO, teachers, on average, felt very confident (5 out of 6).

Teachers grew just slightly in their confidence facilitating student-led conversations to draw out observations; but teachers started PD feeling confident in this, so room for growth was smaller.

One skill that teachers entered feeling extremely confident in already was admitting to students when they didn't know something about a piece of artwork. This measure showed very little change, as teachers remained very comfortable being honest about the limits of their own knowledge.

Change in confidence using arts-based teaching practices before and after BIO.

Teachers rated each statement on a 6-point scale, with 1 being 'Very untrue of me' and 5 being 'Very true of me.'



*Significant difference between time periods
*p<.05, **p<.01 (Wilcoxon signed-rank)

RESULTS

Data Practices and Value

What Teachers Value about Data in the Classroom

Teachers entered BIO already highly valuing professional data. Overall, only one theme was more frequently mentioned after completion of BIO PD.

The area of slight increase post-BIO was that more teachers saw the value of professional data to support claims and draw conclusions. This often went hand in hand with data-related curriculum requirements, such as adherence to NGSS. On the flipside, teachers no longer focused on the value of data to fact-check others' statements (which was a frequent theme in pre-interviews).

Over half of teachers reported that data was of value for making science real or relevant. While this sentiment came up equally in pre and post interviews, it tended to be a post-BIO takeaway for Cohort 1 while it was a more common pre-BIO value among Cohort 2 (and not repeated in post).

Understanding visual data accurately was valued at both time periods, although the way teachers talked about it changed post-BIO. Teachers tended to talk more about understanding that had *flexibility* and awareness of the multitude of information that data viz could convey, rather than students getting a correct answer about a graph.

What teachers valued about teaching with data, before and after the BIO PD.

The numbers below indicate how many teachers touched on each theme at least once in their pre-PD interview, and/or in post-PD interviews (occurring after PD 1 and/or PD 2, depending on cohort).

Complex, professionally-collected data helps students...

	Pre	Post-PD	(n=10)
—	6	6	**Feel science is real, authentic, or relevant** Professional data feels more important or relevant because it's real, authentic, or recognizable to students.
^	3	5	**Support claims and draw conclusions** Value in the process of using data to generate questions, make claims, or supporting assertions with evidence.
^	3	4	**Understand visualized data accurately** Value in helping students learn to "read" or really understand what data and/or visualizations convey or the many things they can convey.
v	3	2	**Think about complexity or the big picture** Large data sets help students look at the bigger picture or generalize about a phenomenon, beyond individual data points.
vv	6	2	**Fact-check assertions or evaluate sources** Finding value in data as a mechanism for students to think critically or fact-check information or to assess the validity and/or quality of a data source.

Their Words: Value of Data Practices

"I kind of get two different opinions about that because just like consumers can misinterpret data, teachers can misinterpret data. And so, we have to know how to read it and understand what it's telling us so that we can properly equip the kids to be able to do the same. The other side of that is when we take a look, when we gather our own data about our kids, in other words, test scores, whatever it is … most frequently missed question, whatever it is. **As long as we're making the right connections with that data, same way, whether it's consumer, whether it's education, whatever it is, we got to know what we're reading**."

-Teacher Interview, Post PD 1

"I think [professional data] has a lot of added value because so often, and at least the curriculum the district provides for us, it is definitely fake data or super simplified data. And so, it doesn't give kids the real-world context of things and so they don't care about it as much, but if you can provide them **real world data, even if it's a little bit more confusing, they're more motivated to figure [it out]** … They're more interested in it."

-Teacher Interview, Post PD 2

"When you see these large numbers and these large datasets, I don't think sometimes the reality of it, it's hard for, again, a seventh or eighth grader sometimes to make those cognitive connections between that. So, **I think it's valuable to start working with it and taking things at a global level and then comparing that to what we're doing at a local level** and, how do you make some sense of all that stuff."

-Teacher Interview, Post PD 1

"But **it's really important that they can use their visual skills to understand what they're looking at** with all this already formatted data that comes with graphs and tables from NOAA, and NASA and the USGS, all that kind of stuff."

-Teacher Interview, Post PD 1

"And so, I often wonder if I am, especially as we move into the realm of disinformation around, and **I'm thinking a lot about climate data, because it's a big part of what I teach. Am I arming them well to be able to push back against disinformation?** It's easy to manipulate data and say, well, let's look at this small piece of that graph, actually, it's going down because you're only looking at five years…"

-Teacher Interview, Pre PD

Changes in Teachers' Valuation of Teaching with Data

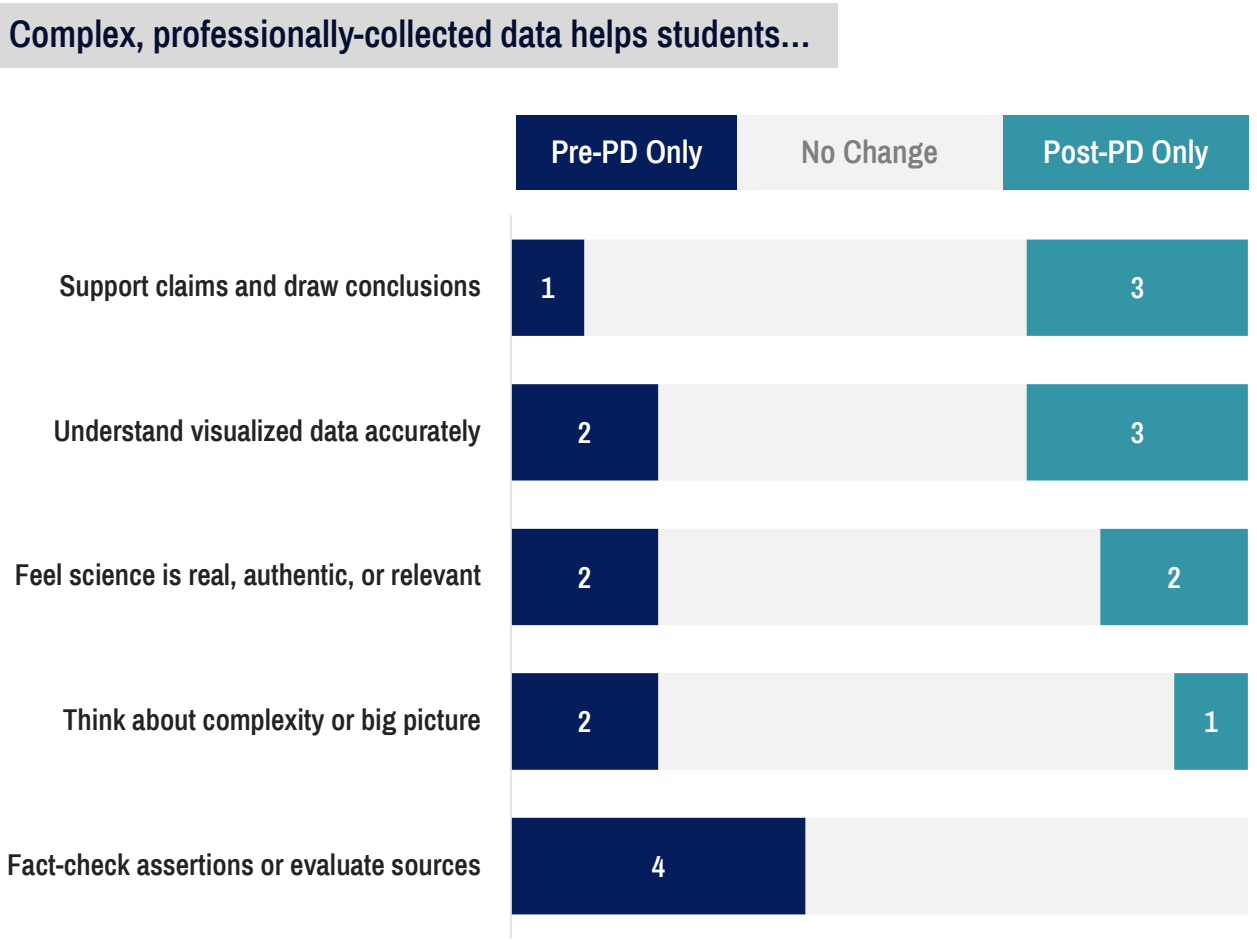
Changes in perceptions of the value of professional data varied for each person. The main shift seemed to be towards valuing data for supporting *student-centered* claims and away from data as a tool for a simple "fact check" of assertions made by others.

Unlike teachers' perceptions of arts-based practices, all teachers seemed to greatly value professionally-collected data as a teaching tool in their classrooms coming into the BIO project. While the value themes shifted, the number of themes mentioned did not expand as they did for the arts (2.1 pre-BIO and post-BIO, on average). Instead, teachers' descriptions within themes became more nuanced, embracing divergent thinking about data and visual representations.

The BIO PD seemed to spur teachers to put greater value on data to make claims and draw conclusions and to comprehend visualized data with a flexible mindset. Their emphasis on data as a tool to challenge misinformation was largely discarded by the end of the BIO project. Together, these signal a major mindset shift in the role of data as a tool for scientific understanding.

How individual teachers' descriptions of the value of using data in science teaching changed after completing BIO PD.

Data are from coded, semi-structured interview responses. The numbers below reflect changes in each individual teacher's ideas. Teal bars show the count of teachers for whom an idea was **newly expressed Post-PD.** Blue bars indicate how many teachers raised an idea pre-PD, but didn't repeat it by their post-PD interview. **Teachers that repeated a theme in both interviews or did not bring it up at all are represented in the central grey bar.**



Classroom Data Practices before BIO PD

All teachers already used data in their classrooms, and most were already using some form of professionally collected data prior to BIO. They often described working on decoding and interpreting data visualizations.

Among teachers who already used professional data in their teaching, it was most common to report they had used pre-made graphs for exercises in decoding or interpreting. It was also common to use professional data as part of project-based learning, in which students sought to solve a problem or answer a key question. BIO, largely, did not introduce these practices to the teachers. However, while a few teachers reported having already taught with professional *geospatial* data visualizations, that was not a widespread practice within either cohort of teachers.

Fewer teachers reported using student-collected data. While one teacher described their students collecting scientific data in fieldwork, most student-collected data that was used was about students themselves, such as height or heart rate. Student data was most often used for practice with data entry, analysis, or creating student-made data visualizations.

Ways teachers included data and data-centered practices prior to starting BIO PD

The numbers below indicate how many teachers touched on each theme at least once in their pre-PD interview to describe how they used data in their classroom already.

(n=10)	Classroom Data Practices Before BIO PD
8	**Data Source: Professionally Collected** Use of professionally collected data in class outside of BIO activities
4	**Data Source: Student-Collected** Use of student-collected data in class outside of BIO activities
9	**Data Activity: Looking and Interpreting** Looking at, decoding, and interpreting pre-made data visualizations
6	**Data Activity: Project-Based Learning** Using data as part of a larger project, to solve a problem, or to answer questions
5	**Data Activity: Data Entry, Manipulation, and Analysis** Entering data, analysis or data manipulation, and creating student-made visuals

"Especially during the pandemic when there were less kids coming to class and doing activities, it was a lot of me just finding data and we did graph of the week, every week. And so, some of the graphs were trickier than others, but that was kind of usually when we used the professional collected data."

-Teacher Interview

"So usually they get their data, they create a research question, or I give them something to measure like their reaction time or their heart rate or how quickly they can do something, and then we analyze that, but even they are aware by doing that, they're like, "Oh, well, we all measure it kind of differently," or "We're all kind of inconsistent." So, they kind of see that the data's inconsistent and they don't really believe in it."

-Teacher Interview

Frequency of Data Practices Before and After BIO

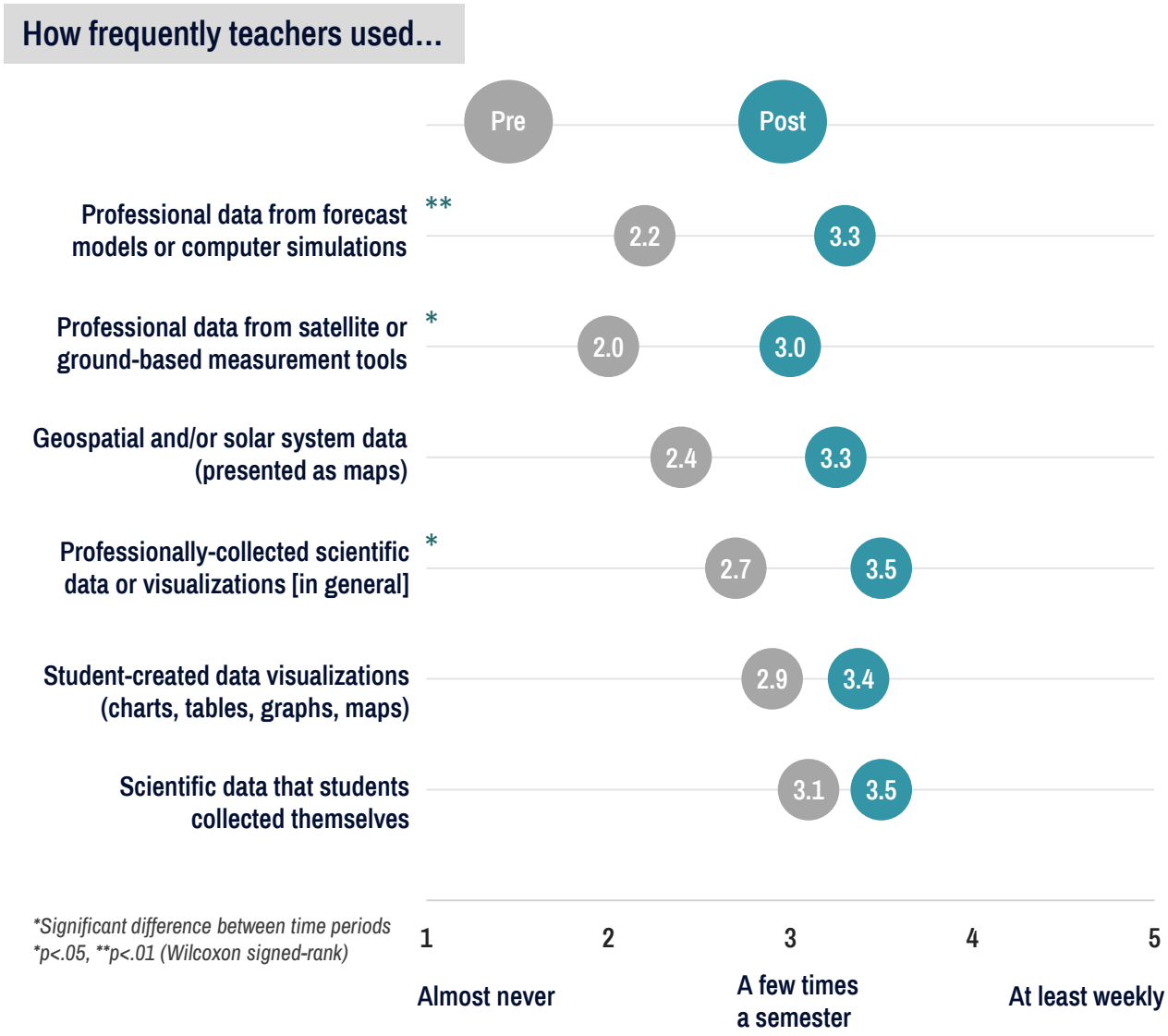
The BIO PD experience seemed to increase the frequency of various data practices in the teachers' classrooms, especially the use of professionally-collected and complex data visualization products.

Teachers reported the greatest gains in frequency of using nuanced, professional data visualization products, including professional forecast models or computer simulations and satellite or ground-based data or visualizations. Use of these types of data shifted from being used a few times a year to a few times each semester, on average. The use of geospatial data and professionally-collected scientific data or representations also increased in its frequency of use, although to a lesser degree.

There was minimal change in the use of student-collected data and visualizations, which was expected as BIO focused largely on professionally collected data and visualizations. However, the use of design thinking elements (Fenceposts and Data Sketches activities; see p. 6 for description) did include some degree of student-generated data (class polling) and visualization (symbols and data sketching). This may contribute to the very slight increase in the frequency of these practices.

Frequency of using data sources and practices in classroom before and after BIO.

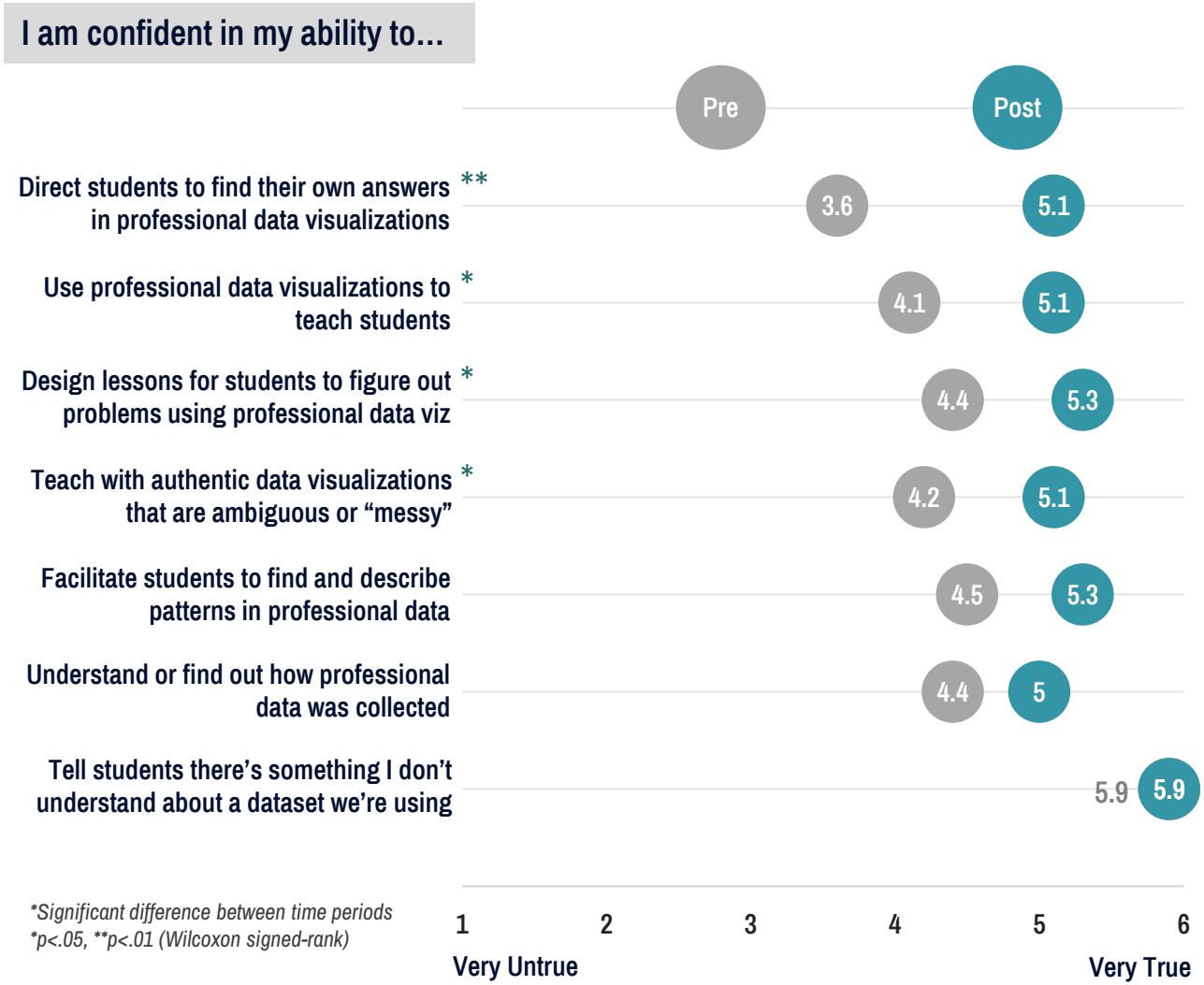
Teachers rated each statement on a 5-point scale, with 1 being 'Never or almost never' and 5 being 'At least weekly.'



Change in Confidence with Data-Based Practices

Confidence using professional data and visualizations in teaching before and after completing BIO PD.

Teachers rated each statement on a 6-point scale, with 1 being 'Very untrue of me' and 5 being 'Very true of me.'



*Significant difference between time periods
*p<.05, **p<.01 (Wilcoxon signed-rank)*

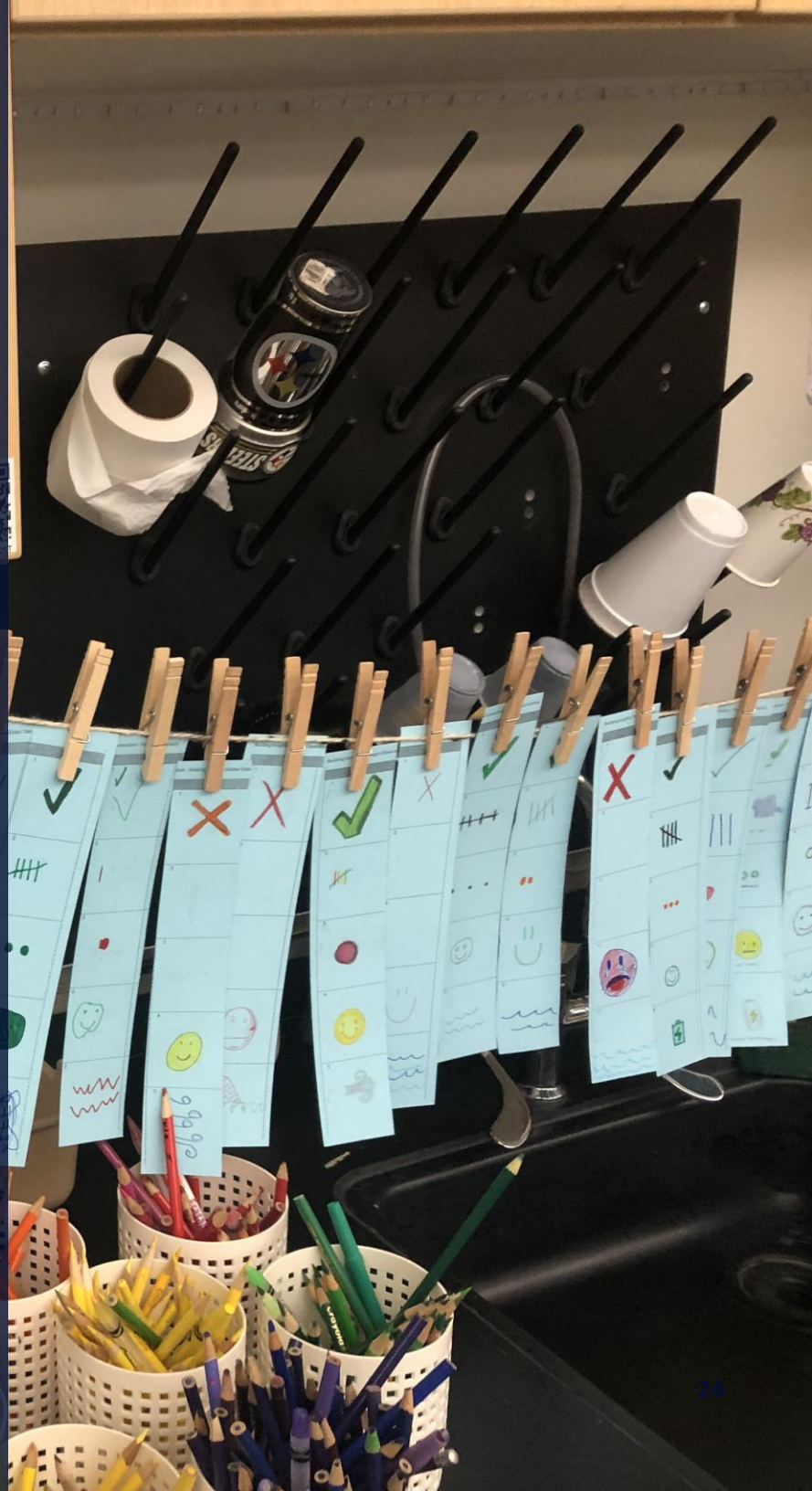
Despite entering the project feeling relatively confident in most skills for teaching with data, teachers reported increases in almost all areas – most notably in their abilities to direct students to find their own answers in data.

Teachers reported the greatest gains in confidence in their ability to direct their students to find and describe patterns, trends, or relationships within professional data visualizations – where they jumped from being in between unconfident and confident, to feeling very confident. Other areas of gain included using professional data to teach students, designing lessons plans that allow students to solve problems using professional data, and teaching with ambiguous or "messy" datasets.

Measures that teachers were quite confident in as they started the project, such as helping students describe patterns and understanding where professional data come from, resulted in smaller growth. As was true with arts-based practices, the measure that did not change was the willingness to admit to not understanding something about the data – all teachers reported extremely high confidence in this prior to starting the BIO PD.

RESULTS

Shifts in Practice and Perspective



Added Value of Using the BIO Approach

Overall, teachers strongly agreed that using arts-based practices and professional data visualizations added value and was class time well spent. Interestingly, the value-add of arts-based approaches were rated even higher than the incorporation of data.

Eight out of ten teachers rated each of the statements about arts-based approaches as "very true," the highest possible rating. Statements about professional data visualizations were split between "somewhat" and "very" true.

While all reactions were positive, the stronger response to the arts-based statements than the data-centered ones may point to how novel these approaches were for the teachers, and thus, how they had the potential to dramatically transform their practices. Most teachers came to the project feeling quite confident working with data; it may be that these elements offered a less dramatic value-add to the teaching practice. Another trend was that Cohort 1 teachers rated the data-centered statements slightly higher than Cohort 2. This may suggest that the learning curve around using global, geospatial data benefited from the longer period of PD and practice.

Teachers' perceptions of the value and time spent on working with arts-based practices and professional data visualizations.

Teachers were asked via survey to rate each statement on a 6-point scale, with 6 being Very True and 1 being Very Untrue. No teachers chose the 'untrue' ratings.

Changes in Teachers' Practices and Mindsets

Teachers described a wide range of ways their teaching practices shifted due to BIO PD, most notably that they began using more complex data, integrated subjects, and generally felt more skilled or confident.

The most common change in practices that teachers reported was shifts in using data in teaching – with teachers using more, larger, and more complex data sets than they would have otherwise. They often noted the big shift to using global data or multiple complex data sets in the Data Sketches activity. Additionally, half of teachers described moving toward more interdisciplinary approaches, wanting to teach science alongside art, geography, and/or history.

The additions of bigger data and interdisciplinary approaches were sometimes related to reporting a greater sense of confidence in trying out new teaching techniques or general feelings of improvement over the course of the BIO PD. Other shifts included discovering the (often surprising) abilities of their students, intentions to try other art-science lessons or units, and two other specific areas of change named by just one teacher each.

Shifts in teacher practices, attitudes, and mindsets after completing BIO PD.

The numbers below indicate how many teachers touched on each theme at least once in their midpoint and/or post-PD interview.

	(n=10)	Teacher Practices and Attitudes
	7	**Using More, Different, or Bigger Data** Use of more data in the classroom, or use of different, bigger, or more challenging data sources of visuals than they would have thought would work in the past.
	5	**Interdisciplinary Approaches** Greater interest in exploring multiple school subjects or disciplines within a single unit or collaborating with teachers in other subjects.
	4	**Increased Confidence and Skills** Feelings that a teacher improved in their ability to use or teach about data, or other feelings of confidence surrounding teaching.
	3	**Recognition of Student Competence or Capacity** Greater acknowledgement that students can do more than the teacher was previously giving them credit for; positive outcomes after challenging students with complex data.
	2	**Intention to Try Other Art-Science Lessons** Intention to integrate the arts in their future teaching, either through brand new art-science activities or significantly expanding/adapting elements of BIO lessons in a new way.
	2	**Other Shifts in Practice** Greater subject continuity throughout the school year and a better understanding of what arts-based approaches really are (not just craft projects or add-ons).

Their Words: Practices and Mindsets

"[Without BIO, I wouldn't have tried] global data analysis, like I said, that just feels like such a big bite to chew. … So, the specific thing that's coming to mind is **the topography and bathymetry map, which is still really hard. … I just wouldn't have even touched on that**. … I was like, "It's too much for them." And maybe it was, but it's okay, it's good for them sometimes."

-Teacher Interview, Post PD 1

"I used a map about population density in cities and wanted to talk about the effect of cities on habitat loss. But even with the population density map, I realized that I hadn't taught the term 'density' and the kids [didn't] understand. And so, it didn't say urban versus rural. It had six categories. And so, it was like, okay, so **I wasn't able to teach everything to it, and I tried to just answer questions on a working level**, but it was a reminder that there's, I think the maps are, I teach sixth grade, so I think at my age level… **I think I better understand to how to teach the different parts of it**."

-Teacher Interview, Post PD 1

"As a science teacher sometimes I feel like, 'Oh, well I can't do something like [art integration] because we need to talk about kinetic energy today.' But I think being able to look at art and have a discussion about it really is valuable in science, and **it made me feel like I had more ways to teach things versus just what I've done in the past, and it made me feel more creative** as a teacher too, instead of being like, 'Oh, well, here's the formula that we got to follow every day.' Instead, it was fun."

-Teacher Interview, Post PD 1

"And so, seeing what the kids would say [during VTS-inspired discussions] without me giving them prompts was really cool. And it showed me that they noticed way more than you give them credit for. That's something I just think about middle school in general, **people don't give middle school kids enough credit… they're just cool little people who are very funny, but they also shouldn't be underestimated**."

-Teacher Interview, Post PD 2

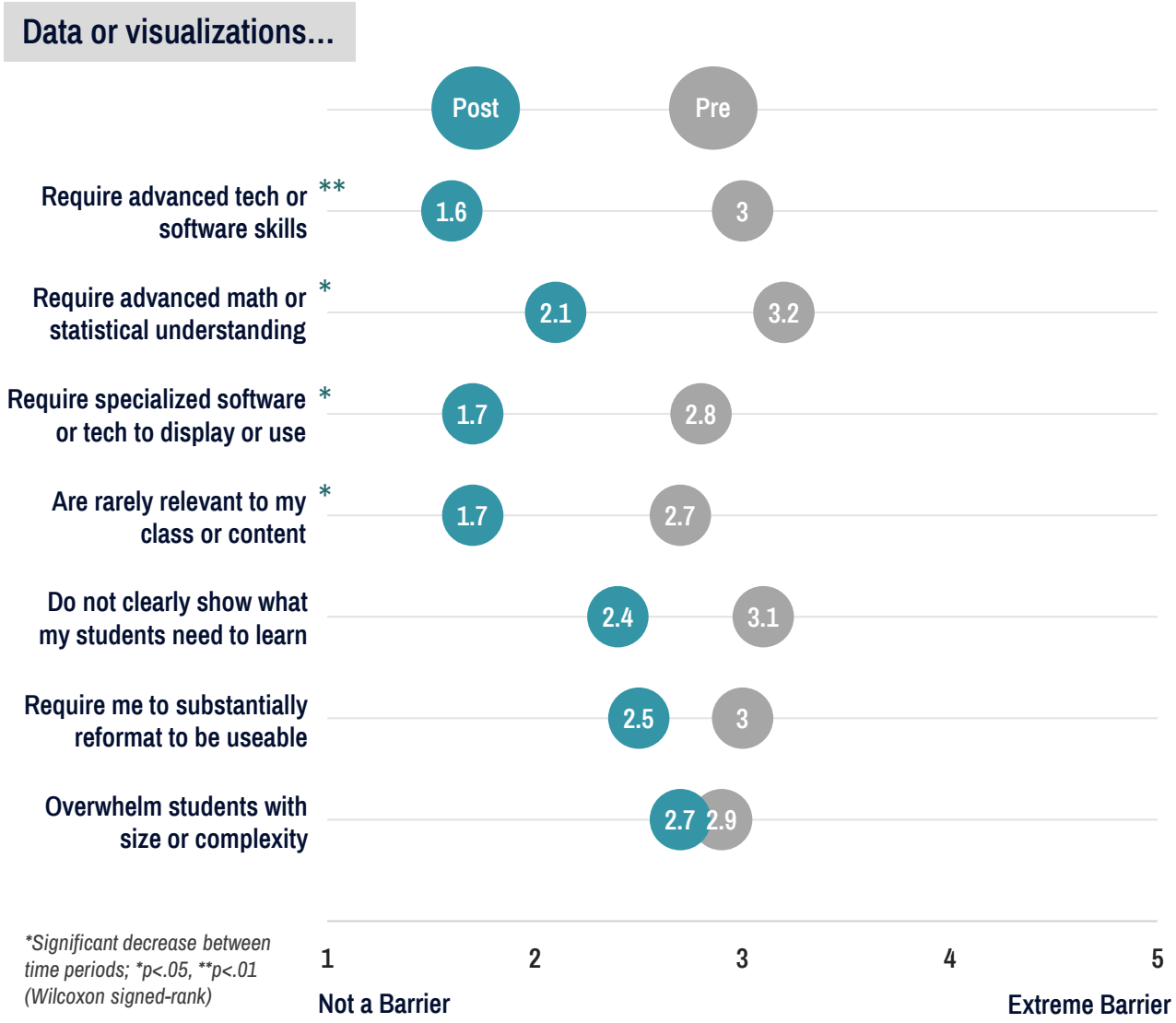
"A world map is just so much more important and relevant to them, they want to be good at knowing what's going on in the world. They want to say, 'Oh, my family's from Sinaloa that's right here'. So, they're creating this understanding of the world. They're tying it into history. They're like, oh, well, we learned from our history class that the Nile River is right here, so I wonder if that's part of it. **And so, it does feel like a lot more interdisciplinary**."

-Teacher Interview, Post PD 2

Reduced Barriers to Using Data After BIO

Perceived barriers to using data or visualizations before and after BIO.

Teachers rated each statement via survey on a 5-point scale, with 1 being 'Not a Barrier' and 5 being 'Extreme Barrier."



**Significant decrease between time periods; *p<.05, **p<.01 (Wilcoxon signed-rank)*

BIO dramatically reduced teachers' sense of many common barriers to using data or visualizations in classroom teaching – particularly around perceived needs for technology and math skills.

The greatest decreases in barriers included the perception that using data or visualizations require the students have advanced skills with technology software, math, or statistics, and that teachers need specialized technology tools and struggle to find relevant data sets.

The change in belief that working with data requires students to have advanced math skills was important. The BIO approach offered a way for students to learn from visualized data, rather than having to begin with their own quantitative analysis. This was a major shift from pre-BIO assumptions held by teachers in the program.

BIO may have addressed barriers surrounding technology access through the PD team's support to identify, access, and prepare relevant NOAA data sets for use in activities. The team found it was difficult to expect teachers to navigate the technology hurdles to do this themselves; without this support, these barriers may have persisted.

Reduced Challenges in Teaching with Data

Within conversations about their experiences, some teachers described how the BIO PD addressed challenges they had previously experienced teaching with data.

From these reflections, the BIO PD process and support seemed to help teachers with a variety of past challenges. These included making it easier to help students understand data, find relevant data sets, embrace complexity in data (rather than feel compelled to simplify it), and engage students in data-centered thinking, even when they have limited math abilities.

While 6 of the 10 teachers named a barrier that BIO helped them overcome, Cohort 1 (with two years of PD) tended to name multiple barriers that were surmounted. Cohort 2 teachers who named a challenge they overcame tended to only see one area of change. The extra year of PD, classroom practice, and support from the PD team for Cohort 1 seemed to pay dividends in terms of creating a sense that the BIO approach had been a robust solution to fix previous setbacks they had experienced in their teaching.

Challenges in teaching with data that BIO PD addressed.

The numbers below indicate how many teachers touched on each theme at least once in their midpoint or post-PD interview.

	(n=10)	Challenges Addressed by BIO PD
	3	**Helping Students Understand or Connect with Data** The BIO lessons or PD gave the teacher strategies that address challenges with students comprehending or working with data and/or complex topics.
	3	**Finding Relevant Data Sets** BIO PD helped teachers feel more able to find data sources that fit their content and curriculum.
	3	**Embracing Complexity in Data** Teachers felt more comfortable including complex or “messy” data in their lessons.
	3	**Teaching Students Despite Limited Math Skills** The BIO lessons helped teachers realize their students could grapple with complex or nuanced data regardless of their math proficiency.
	2	**BIO Revealed New Challenges** Teachers that highlighted continued or newly discovered challenges as they completed the BIO lessons and PD.

Their Words: Data Challenges Addressed by BIO

"So not only am I very proficient in [teaching with data] now, I feel like I understand it, but it's like this library is all I use. So, I went into it for weather and climate. I went back to it for human impacts, **and it just feels really cool to be like, okay, if I am interested in doing a project about anything, I'm just going to go look up here first and see what they have**. And then not just the dataset library that we use, but also the other websites that we use."

-Teacher Interview, Post PD 2

"Really focusing in on that data and spending time on it … has **helped us think through what it means to have a data set that's the entire planet averaged over an entire month, let's say, and then we're comparing that entire planet's worth of data for entire month to an entire century's worth of data**. How can you possibly gather all that data and process it and make this beautiful graph? I think we've had some interesting conversations with kids, and I don't really think I've focused in on that as much in the past. And so, I credit the program for helping me slow down with those kinds of questions."

-Teacher Interview, Post PD 2

"Earlier on in the project I had mentioned or had thought about how oftentimes the data would need to be processed or whatever to be more age appropriate or simplified, so it's less going on perhaps. And I feel like from having used the maps and the data, obviously **there's a huge amount of data or a huge amount of value in using the data, and it's great in terms of how it paints an accurate picture of what's going on depending on the topic**."

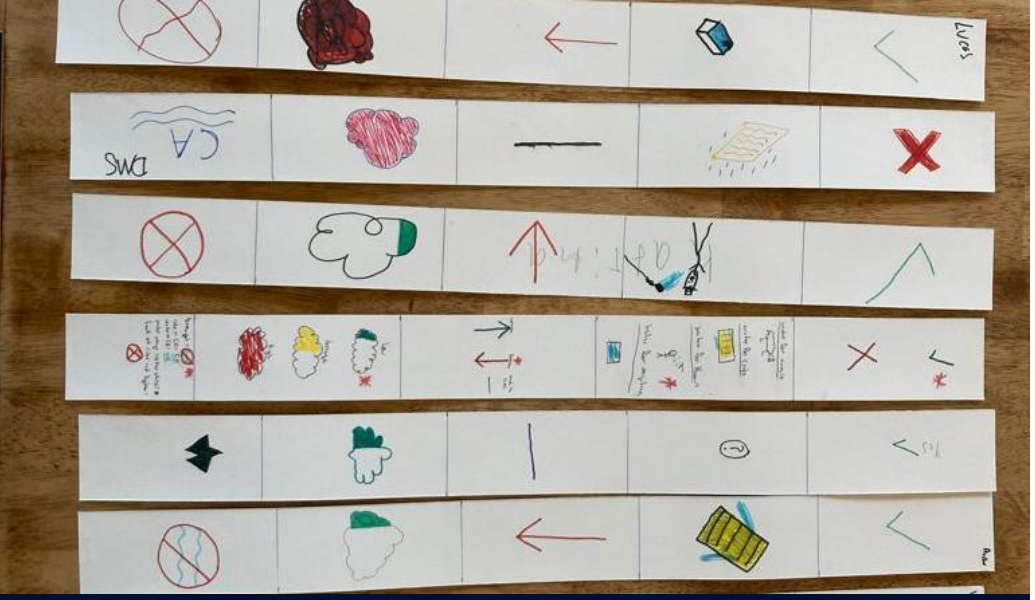
-Teacher Interview, Post PD 1

"I think before I was a lot happier using the textbook data just because especially sixth grade, their math is pretty limited. Their understanding of units pretty limited. So, I was very hesitant to use real data just because of the complications of the numbers, the scale, explaining the categories. **But I think this process has helped me realize they don't have to fully understand that, to understand the patterns of what's going on in a map.** So, I feel a lot more willing to tackle it."

-Teacher Interview, Post PD 1

CONCLUSIONS

Shifts in Teaching Practice, Attitudes, and Values



Conclusions

>> Shifts in Attitudes and Values

Teacher participants in the Building Insights through Observations project showed notable shifts in their teaching practices, their attitudes towards teaching with complex data and the arts, and the ways in which they described value in data and arts-based practices in science teaching. The changes were slightly different as it related to arts-based or data-based practices, reflecting the level of familiarity teachers had with each domain when they entered the project. Taken together, we saw an increase in use of complex, professionally collected data in the classroom and a broadening of perceived value of integrating arts-based practices to enhance student learning in science. Teachers agreed that using both art and data during class was valuable for students and was time well spent.

1

Greater Confidence in Arts & Data Use

Teachers consistently reported their confidence increased in specific teaching practices following BIO PD – for both arts- and data-based practices. This seemed especially true for more student-directed teaching practices and integrating art practices into science curriculum. Reflections reiterated this shift, as they described stepping outside their comfort zones, trying more challenging data sets than they had before, and centering arts-based practices in the classroom.

2

Seeing Much Greater Value in the Arts

The changes in teachers' mindsets around the value of arts-based practices showed some of the greatest growth by the end of the project. There were dramatic increases in the number of ways that teachers could articulate the value of the arts to their teaching. Results showed that teachers shifted from seeing the arts as a "fun" way for students to show comprehension to a useful tool for students to build skills, habits of mind, and take ownership of their learning. Ratings of the value-add of BIO's arts-based practices reflected the profound shift in teachers from this work.

3

Deeper Value & Frequent Use of Data

For teaching with professional data, the shifts in mindsets were different. Teachers already valued data at the outset, so the breadth of their thinking about its value did not change. What *did* shift, however, was the types of values of data that each teacher noted – as well as the nuance in how they described it. Teachers shifted from seeing data as a way for students to get to right answers from scientists ("fact checking"), and instead as a way for students to construct their own interpretation and understandings. Moreover, teachers reported much more frequent use of complex, professional data in the classroom – a shift that did not occur for arts practices (which remained relatively infrequent).

Considerations for Future PD

The Value of 2-Year PD & Practice Cycle

When examining post-project interviews, we saw that Cohort 1 teachers (who had experienced two full cycles of PD, coaching, and classroom implementation) brought up a broader range of outcomes than Cohort 2. There were notable differences in the ways they valued the arts, shifts in their attitudes and practices, and challenges addressed. In their concluding interviews, Cohort 2 teachers tended to focus more on reflecting about their first-year implementation – what they would like to change or struggled with, if they were to do it again. These conversations were very similar to what Cohort 1 reported after their first year in BIO. This underscores the value of offering multi-year PD to change teacher mindsets. The degree of shifting practices – and moving teachers out of their comfort zones – is difficult to achieve in just one year.

By having two years of support, Cohort 1 teachers could spend one year experimenting with implementation, and another year polishing their lessons and reflecting on the full benefits of the BIO model for themselves and their students. However, this implication suggests there may be limitations to achieving impact in practice if future PD approaches use a “breadth” model (e.g., short PD to reach lots of teachers or DIY self-taught resources) versus a “depth” model of supporting fewer teachers with personal coaching to improve their practice over more time.

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