Visualizing Authentic Data and Supporting Learning about Weather, Climate, and Seasons with Colorful Weather Trackers

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Abstract

In fall 2023, I designed a means for the pre-service teachers (PSTs) in my Earth-Space Science class to engage with authentic data and co-construct data visualizations—weather trackers—to enable them to track daily temperature and precipitation data over time. I did so to support their data literacy, data visualization literacy, and abilities to analyze and interpret data, make sense of patterns, and make evidence-based arguments about climate and seasonal temperature differences. We examined weather in three locations: our local area and two mystery locations. Each location had one weather tracker for daily maximum temperature and one for daily total precipitation. Most weeks of the semester, the PSTs spent about 15 minutes knotting a piece of yarn to each tracker for each day of the preceding week, according to data reports from the National Weather Service and National Oceanic and Atmospheric Administration (NOAA). We used a key whereby certain colors of yarn corresponded to certain temperature and precipitation ranges. Throughout the semester, PSTs reflected the data displayed on the trackers. Ultimately, PSTs were able to make arguments about the probable designated climate zones and relative latitudes for the two mystery locations. In this paper, I share the design and implementation of the weather trackers, how my students and I grappled with messy authentic data, and how the weather tracker data visualizations contributed to PSTs' sensemaking about climate and seasons.

In this instructional innovation, students enrolled in an Earth-space science class for elementary preservice teachers (PSTs) engaged in a semester-long effort in which they (1) represented authentic temperature and precipitation data in a physical data visualization, (2) made sense of the weather patterns evident in the visualization, and (3) made arguments about climate and seasonal differences in temperature based on those patterns. The aim of this innovation was to simultaneously support the PSTs' data literacy, data visualization literacy, and content knowledge concerning weather, climate, and seasons.

Data literacy has been defined as students' abilities to "understand and evaluate information obtained from authentic data" (Kjelvik & Schultheis, 2019, p. 2). Authentic data is data gathered in the real world. Bowen and Bartley (2020) juxtaposed authentic data with those that have been sanitized— cleaned up and simplified— as is often the case for data used in school-based science. Authentic data are often described as being messy, i.e., having outliers, a wider variability due to natural and experimental causes, or missing data (Bowen

& Bartley, 2020; Kjelvik & Schultheis, 2019). Such messiness provides more robust opportunities for students to analyze, interpret, and find patterns in the data and then make evidence-based arguments based on the data (Kjelvik & Schultheis, 2019). These behaviors are supported by *The Framework for K-12 Science Education* and the *Next Generation Science Standards* (NGSS), specifically regarding the Scientific and Engineering Practices of "Analyzing and Interpreting Data" and "Engaging in Argument from Evidence" and the Crosscutting Concept of noticing and articulating patterns (National Research Council, 2012; NGSS Lead States, 2013).

Data visualization literacy is related to data literacy. A data visualization is a visual representation of data. Traditional examples include tables, graphs, and figures. Bowen and Roth (2002) referred to these as scientific inscriptions and suggested they can be challenging for students to interpret, especially in their streamlined yet sometimes unclear or incomplete form within textbooks. Other examples include pie charts and data depicted on maps. Common data visualizations in the popular press are information graphics or infographics (Gebre, 2018; Gebre & Polman, 2016). Many data visualizations include some form of color coding like value, hue, or saturation, to depict different data types (Börner et al., 2019). Regardless of the type of data visualization, citizens are likely to engage with scientific data through these visualizations; thus, it is vital for students to learn to make sense of them (Börner et al., 2019; Börner et al., 2016; Gebre, 2018; Gebre & Polman, 2016). In other words, students should develop their data visualization literacy, i.e., "the ability to make meaning from and interpret patterns, trends, and correlations in visual representations of data" (Börner et al., 2016, p. 200).

Gebre and Polman (2016) and Gebre (2018) argued that students need practice at both (a) interpreting data visualizations that experts have constructed and (b) constructing their own data visualizations. The latter of these is less common in the literature and in classrooms (Börner et al., 2019; Gebre, 2018; Gebre & Polman, 2016). However, as Gebre (2018) argued, data visualizations "are not just resources to *learn from* but also cognitive tools to *learn with*," especially when students participate in their construction (Gebre, 2018, p. 5, emphasis in text). Both Gebre and Polman (2016) and Gebre (2018) described how secondary school students generated and improved infographics for use in science news reporting. Constructing such a data visualization requires that its designer(s) consider the stakeholders who might benefit from it; how the data will be acquired; how the data will be analyzed, prepared, and added to the visualization; how the visualization will be deployed (e.g., on paper or via some electronic means); and how data will be interpreted (Börner et al., 2019).

Echoing Gebre's (2018) assertion that data visualizations are cognitive tools to *learn with*, I set out to have the PSTs in my Earth-space science class add authentic data to a color-coded data visualization—what I call a weather tracker data visualization (hereafter, "weather tracker")—that I designed to track daily maximum temperature and daily total precipitation values for three locations in the United States (US). These were our local area and two mystery locations. I did so to engage the PSTs with authentic weather data, support their data literacy and data visualization literacy, and support their learning about climate, climate zones, and seasons.

In past years of teaching the course, I have relied on broad descriptions (e.g., temperature ranges) of Köppen climate zones and examples of locations within those zones. I also used sanitized data within computer-based simulations like ExploreLearning® Gizmos to represent annual temperature and other data (e.g., solar energy) for locations at different latitudes. These sanitized forms of data and ready-to-interpret data visualizations were useful in helping my PSTs understand broad patterns and relationships, yet they were disconnected from authentic data.

The Course and PSTs

Nine PSTs were enrolled in my Earth-space Science class during the semester in which I implemented and integrated the weather trackers. The PSTs were largely, but not exclusively, female, White, and not Hispanic. This is about half the size of most of the 23 sections of this class I have taught over the years. It is also less diverse than has been typical in recent years. The class I describe in this paper met once per week for about 3.5 hours. This 3-credit combined lab-lecture course designed for elementary PSTs addresses content related to geology, light, climate change, and astronomy. Most PSTs I teach have had limited opportunities to analyze actual scientific data. Further, and relevant to our investigation of seasons during the astronomy unit, many come to the class with the alternative conception that the proximity of the Earth to the Sun is the primary reason for seasonal temperature changes. That said, these PSTs have many assets, including curiosity about the world around them, and most respond well to the active, inquiry-based learning strategies (Arthurs & Kreager, 2017) that I use in the class.

Design of the Weather Trackers

I was the primary designer of the weather trackers, but my PSTs were the primary individuals who added data to these visualizations. In so doing, I positioned my PSTs as the stakeholders, determined how we would acquire the data, and prepared the trackers to receive data added by PSTs, enabling them to interpret this co-created data visualization (Börner et al., 2019).

Temperature and Precipitation

I decided that my PSTs would track daily maximum temperature and total daily precipitation. I chose the daily *maximum* temperature, not the daily low or average, since the maximum often occurs during the day when most are able to experience it first-hand and it is less abstract than the average. Temperature and precipitation are familiar to my PSTs (e.g., reported on weather apps) and likely to be familiar to the elementary students they would teach in the future. Also, temperature and precipitation data could provide clues about the climate and latitude of a particular area, albeit not the only clues.

The “NOWData” portion of the open-access National Weather Service (NWS) and National Oceanic and Atmospheric Administration (NOAA) website (NWS & NOAA, 2024) provides these and other data from weather stations across the US, with daily maximum temperature in degrees Fahrenheit and total daily precipitation in inches. The website enables users to create various reports of past weather data, including a “Daily Data for a Month” report that shows daily temperature and precipitation data for any full or partial month that has transpired. See Figure 1 for a report for our local area in August 2023.

Figure 1

Local NOWData

Climatological Data for ABERDEEN PHILLIPS FLD, MD - August 2023									
Date	Temperature				HDD	CDD	Precipitation	New Snow	Snow Depth
	Maximum	Minimum	Average	Departure					
2023-08-01	84	65	74.5	-2.0	0	10	0.00	0.0	0
2023-08-02	80	59	69.5	-7.0	0	5	0.00	0.0	0
2023-08-03	80	60	70.0	-6.4	0	5	0.00	0.0	0
2023-08-04	80	66	73.0	-3.3	0	8	0.00	0.0	0
2023-08-05	79	68	73.5	-2.7	0	9	0.00	0.0	0
2023-08-06	83	68	75.5	-0.7	0	11	0.00	0.0	0
2023-08-07	86	68	77.0	0.9	0	12	0.59	0.0	0
2023-08-08	88	70	79.0	3.0	0	14	1.03	0.0	0
2023-08-09	83	65	74.0	-1.9	0	9	0.00	0.0	0
2023-08-10	86	65	75.5	-0.3	0	11	0.00	0.0	0
2023-08-11	78	68	73.0	-2.7	0	8	0.21	0.0	0
2023-08-12	86	69	77.5	1.9	0	13	0.00	0.0	0
2023-08-13	89	67	78.0	2.4	0	13	0.00	0.0	0
2023-08-14	89	67	78.0	2.5	0	13	0.00	0.0	0
2023-08-15	90	68	79.0	3.6	0	14	0.48	0.0	0
2023-08-16	90	71	80.5	5.2	0	16	0.01	0.0	0
2023-08-17	84	66	75.0	-0.2	0	10	0.00	0.0	0
2023-08-18	89	66	77.5	2.5	0	13	0.00	0.0	0
2023-08-19	82	57	69.5	-5.4	0	5	0.00	0.0	0
2023-08-20	80	58	69.0	-5.8	0	4	0.00	0.0	0
2023-08-21	85	59	72.0	-2.7	0	7	0.00	0.0	0
2023-08-22	90	68	79.0	4.4	0	14	0.00	0.0	0
2023-08-23	81	57	69.0	-5.4	0	4	0.00	0.0	0
2023-08-24	80	58	69.0	-5.3	0	4	T	0.0	0
2023-08-25	76	68	72.0	-2.1	0	7	0.03	0.0	0
2023-08-26	88	70	79.0	5.0	0	14	0.00	0.0	0
2023-08-27	89	67	78.0	4.2	0	13	0.00	0.0	0
2023-08-28	87	67	77.0	3.4	0	12	0.00	0.0	0
2023-08-29	78	70	74.0	0.6	0	9	T	0.0	0
2023-08-30	81	71	76.0	2.7	0	11	0.02	0.0	0
2023-08-31	85	64	74.5	1.4	0	10	0.14	0.0	0
Sum	2606	2030	-	-	0	308	2.51	0.0	-
Average	84.1	65.5	74.8	-0.3	-	-	-	-	0.0
Normal	84.4	65.8	75.1	-	1	314	4.21	M	-

Observations for each day cover the 24 hours ending at the time given below (Local Standard Time).
Max Temperature : 7am
Min Temperature : 7am
Precipitation : 7am
Snowfall : unknown
Snow Depth : 7am

Locations

I selected three locations for the class to investigate. The first location was local, with data gathered from a weather station in the same county where I taught my PSTs. This location in the mid-Atlantic US is designated as the major climate zone, Köppen Climate Zone C, Moist Subtropical Mid-Latitude (NOAA, 2023). Gathering local data was an important aspect of the activity because it related to the lived experiences of the PSTs.

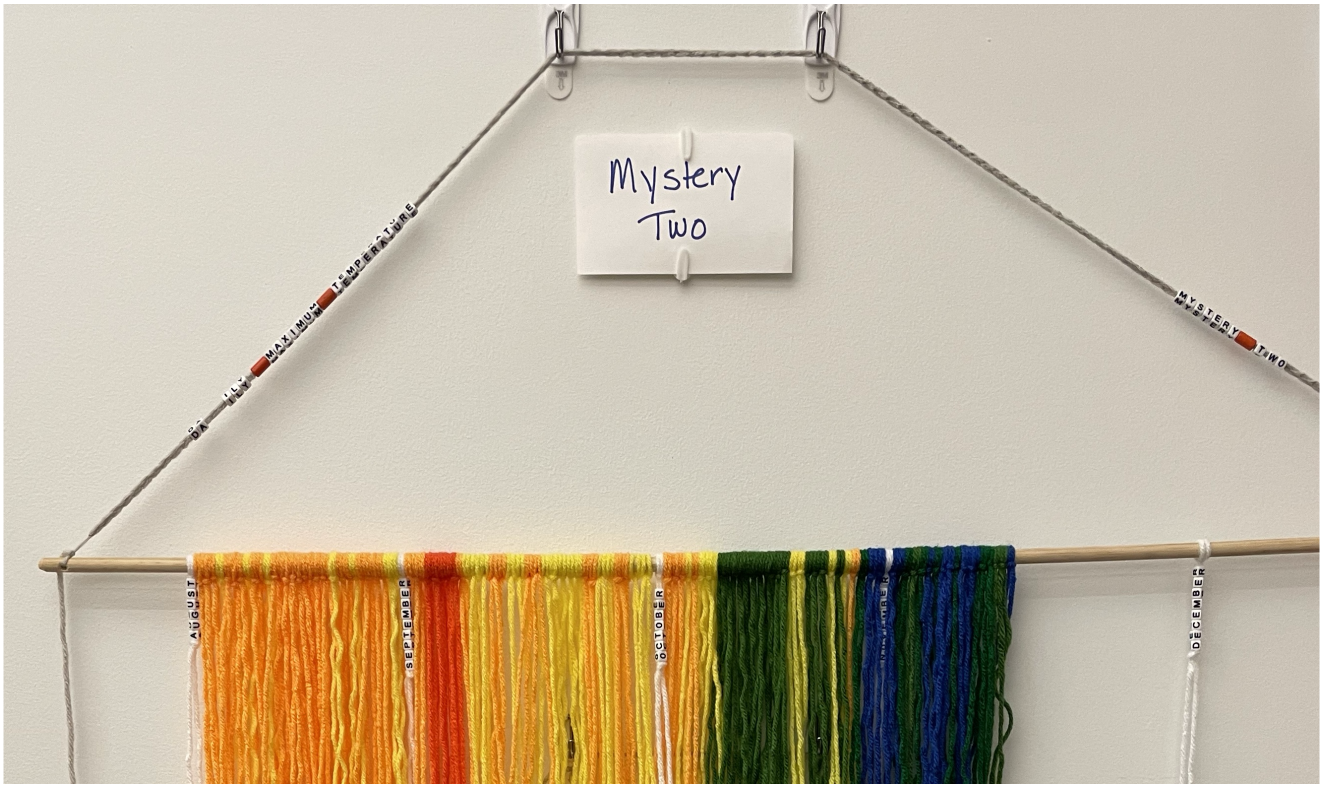
I constrained the two additional locations to be set in the US and have a weather station that reported to the NOWdata database (NWS & NOAA, 2024). This allowed our data to be reported in a similar way across all three locations. I selected two locations designated as different major climate zones and that had different latitudes, but that had similar elevations and similar proximity to a large body of water as our local area (so that variation in weather was less attributable to elevation or proximity to water). Ultimately, I selected Miami, Florida, and Caribou, Maine, known to my PSTs until the end of the semester as Mystery Locations 1 and 2, respectively. Miami is designated as Köppen Climate Zone A, Tropical, and Caribou is designated as Köppen Climate Zone D, Moist Continental Mid-Latitude (NOAA, 2023).

Building Weather Trackers and Creating the Keys

Each location had two weather trackers, one for daily maximum temperature and one for daily total precipitation; thus, there were a total of six trackers for our class. Each empty tracker— awaiting data in the form of yarn— looked like a large coat or clothing hanger. (In fact, an actual clothes hanger could be used for a semester's worth of data instead of creating your own, as I describe here.) I constructed each tracker using a half-inch (about 1 cm) diameter wooden dowel, about 36 inches (91 cm) in length, and tan-colored yarn that I crocheted in a chain to make a means of hanging each tracker. See Figure 2 for a partially full tracker that shows the dowel, tan chain of yarn, and bead labels described in the next paragraph. The yarn I used for this part of the tracker and the colors that represented data was an affordable yarn available in many colors from a big-box craft store.

Figure 2

Temperature Weather Tracker Showing Labels



Using the crocheted chain of yarn as the means to hang the trackers enabled me to thread letter beads on the chain to identify each tracker. On one side, the type of data, either daily maximum temperature or total daily precipitation, was displayed using the letter beads. On the other was the location information, with letter beads spelling out either Local, Mystery 1 or Mystery 2. To further prepare the trackers for data collection, for each tracker, I used white yarn and letter beads to mark the names of each month for which we would be collecting data: August, September, October, November, and December. The August data was to be hung between the August and September markers, and so on. I hung removable hooks on the walls of my classroom to display the trackers throughout the semester. My PSTs were in the classroom during my class and another on a different day of the week. I hoped that seeing the trackers would inspire wonderings and communication among my PSTs, even outside of my class. Indeed, I learned that the PSTs discussed the trackers with at least one of their other professors.

I created keys so that numbers in the NOWData reports (NWS & NOAA, 2024) could be translated into colors of yarn. I used colors of the rainbow to represent different bands of temperature (Figure 3).

Figure 3

Temperature Key

I used different shades of blue to represent different levels of precipitation; the darker the blue, the heavier the precipitation (Figure 4).

Figure 4
Precipitation Key

PSTs Adding Data to the Weather Trackers

Before the semester started, I had not only constructed the trackers but also populated each of them with data from the beginning of August through seven days prior to the first day of class. These early days of August would serve as examples of how the yarn on the tracker corresponded to the data in the NOWData report (NWS & NOAA, 2024) and the color-coded key for the trackers that they would see on this first day of class.

On the first day of class, before introducing my PSTs to the weather trackers, I facilitated a discussion with the PSTs about the daily relevance of weather to our lives and that teaching about weather is a part of teaching elementary science (National Research Council, 1996, 2012; NGSS Lead States, 2013). We considered how people measure temperature (e.g., with thermometers) and precipitation (e.g., with rain gauges). I then played a short video demonstrating how a simple weather station worked (JBA Trust, 2021). The station included an automatic and manual rain gauge, as well as a temperature sensor. The video explained how the data from the station were collected, transmitted, and made available for use at the station and online. I explained that we would be tracking daily maximum temperature and daily total precipitation data from weather stations just like the one we observed in the video and showed the PSTs the NOWData website (NWS & NOAA, 2024) we would be using.

Nearly every day of class, I asked the PSTs to add the previous seven days of data to the trackers. There were a few times that I added data for my PSTs (e.g., on an exam day). PSTs worked in three groups. Each day they added data to the trackers, I assigned each group to a different location and asked them to work together to populate the temperature and precipitation trackers with data from that location. I ensured that all groups had an opportunity to add data to trackers for each location multiple times throughout the semester. I provided each group with the keys and paper data reports from NOWData (NWS & NOAA, 2024). Because my desire was to keep the mystery locations hidden, I did not have my PSTs look up data on the NOWData site for themselves. Prior to class, I simply cut off the location information from the reports for the two mystery locations and relabeled them by hand as Mystery Location 1 and Mystery Location 2. I provided meter sticks and scissors to each group and placed boxes of yarn, one for temperature and one for precipitation, in the classroom. During their work to populate the trackers, each group divided up the labor: determining what colors of yarn they would need; cutting the yarn to about 1 meter in length for each day; folding the yarn in half; and looping/knotting it over the dowel; and making certain that the yarn was placed according to date from left to right in between the month markers. Each day, it took about 15 minutes for all three groups to populate the trackers. For a larger class size, it would be possible to divide into six groups, each populating just one weather tracker (temperature or precipitation) for a given location, reducing the time it would take to populate the trackers.

As we began data collection, we noticed that there were some days when data were missing; this is one aspect of messy authentic data (Bowen & Bartley, 2020; Kjelvik & Schultheis, 2019). As the NOWData site suggests, this can occur if “the data did not make a quality check, there was an equipment outage, or … the observer was not available at a manual station” (NWS & NOAA, 2024, n.p.). We discussed how to address this in our trackers, ultimately deciding to represent missing data with black yarn and replacing the black yarn if data became available at a later time, as it sometimes did. Missing data, we discussed, was a reality in some types of data collection in science; however, if missing data was within a larger data set, patterns could still be surmised. We also noticed that, at times, a “T,” standing for “trace,” was shown for precipitation. We decided to include this in the 0.01 to 0.49” precipitation category (Figure 5) since it represented some non-zero amount of precipitation.

Figure 5
Mid-Semester Trackers

Another special circumstance arose in November with Mystery Location 2, which started experiencing snow. Together, the PSTs and I noticed how the NOWData report (NWS & NOAA, 2024) provided both daily precipitation and new snow amounts, which differed. The PSTs learned that the snow amount was measured directly, while the precipitation amount was based on the level of water from melted new snow to equate it to liquid forms of precipitation in the record. I brought in silver sparkly yarn to add to the colored precipitation yarns to represent when it snowed. During the semester, we only observed snowfall for Mystery Location 2.

Making Sense of the Data

Daily Discussions

Each day that we added data to the trackers, we had a short discussion of the patterns that the PSTs noticed in the trackers that they collectively populated. Questions I used to facilitate this discussion included: What do you notice about the data you added this week? Does the local data resonate with what you experienced over the past week? How does it relate to the data from previous weeks? How are the patterns similar or different across the trackers? Did anything in the data surprise you? We discussed unexpectedly higher or low temperatures, rain events, missing data, and snow. PSTs regularly guessed at the location of the mystery locations and often offered what it would be like to be there instead of experiencing our own local weather.

Mid-Semester Climate Zone Assignment and Discussion

Mid-semester, and as part of our unit on climate and climate change, I had assigned PSTs to read (a) a teacher practitioner article about teaching concepts of weather and climate (Royce, 2020) and (b) a website that briefly described the six major Köppen Climate Zones (NOAA, 2023). I asked the PSTs to answer several questions about these resources, including about the identity of our local climate zone, which they all identified correctly (Supplemental Resource A). I also asked the PSTs to guess which Köppen Climate Zones might correspond to the mystery locations. They were to respond with a good guess based on the over two months of data in our trackers and their brief learning about the climate zones. Guesses for Mystery Location 1 were Tropical Zone A (5 of 9 PSTs) or Dry Zone B (4 PSTs). Guesses for Mystery Location 2 were Moist Subtropical Mid-Latitude Zone C (1 PST) or Moist Continental Mid-Latitude Zone D (8 PSTs) (NOAA, 2023), and included the following reasoning.

Mystery Location 1 as Tropical: “Mystery location 1 has nearly all dark red string. This means that this location is very often hot. This relates to the description of the tropical climate zone … and there has also been precipitation often enough that it could be an average of 59” of precipitation annually.” (PST #9)

Mystery Location 1 as Dry: “Temperatures are very high, and there is not enough precipitation for it to be a tropical environment. Therefore, it must be a dry climate since this is the only other climate with higher temperatures.” (PST #3)

Mystery Location 2 as Moist Subtropical: “… because when I look at the data, the temperature seems pretty warm with little no extremes, but not too warm. Also, the rain fall seems mild.” (PST #2)

Mystery Location 2 as Moist Continental: “… because it says it has warm to cool summers, and this location has range between 60-79 degrees from August to now. The precipitation has also mostly been 0.01-0.49 inches, which is a lot less than a tropical climate, which is why I know this isn’t a tropical location.” (PST #6)

We discussed these guesses as we looked at the trackers (Figure 5), allowing the correct answers to be unknown for the time being.

Mid-Semester Climate Change Connection

Mid-semester and following a geology unit, PSTs learned about climate change through a hands-on ice core activity (Byrd Polar and Climate Research Center, 2024). They also completed an assignment that involved reviewing resources I posted to our learning management system (e.g., videos from the Environmental Protection Agency and Scripps Oceanography) and responding to questions about those resources. Those resources and questions focused on topics such as the Greenhouse effect, the Keeling curve, how carbon dioxide is measured in the air, ice core drilling, and the Vostok Ice Core data. The final question on this assignment connected to our weather trackers and asked: “What might rising temperatures mean for our climate or the climate of Mystery Location 1 or 2 in, say, 50 years?” Responses included:

“Rising temperatures in Mystery Location 2 in 50 years would be much hotter, resembling a less mild summer and instead a much hotter summer. We did not see many hot days over the summer for Mystery Location 2, many days were in the 70 degrees with an occasional day in the 80 degrees. I would expect that this would change in 50 years if CO_2 continues to rise in this way, and instead [of] this mild summer, the location would experience hotter summer days such as mostly 80 degrees and even reaching 90 degrees on occasion too.” (PST #3)

“The mystery location [1] with already hot temperatures could be unbearable with blistering, scorching heat. Or draughts from the high temperatures. Storms could wreak havoc on the environment as temperatures get extreme.” (PST #4)

“I think that the average temperature in the areas will increase as well as the amount of precipitation. This could cause more natural disasters and greatly impact all living beings in that area.” (PST #7)

Overall, and not surprising given the question, the PSTs responded by suggesting that the temperatures at one or more locations would be higher. Six of the nine PSTs also indicated some change in precipitation, yet how precipitation would change varied across PSTs. We discussed how climate change indeed includes increased temperature, but that it also increases variability in the subsequent weather that we experience.

End-of-Semester Assignments and Discussions

As part of the astronomy unit that transpired between the climate change unit and the end of the semester, the PSTs learned about latitude and the reason why latitude, a key variable that influences climate due to its relationship to sun angle, affects seasonal temperature differences. Although these differences can occur without a change in latitude, my emphasis in this course is on latitude as the most influential variable with respect to climate. In their exploration of the sun angle on seasonal temperature changes, they learned that, in general, higher latitudes in the northern hemisphere receive lower sun angles than lower latitudes on the same day at the same time. They also learned about seasonal differences when comparing the northern and southern hemispheres, with these hemispheres experiencing opposing seasons (e.g., fall in the northern hemisphere is spring in the southern hemisphere). PSTs' trackers were now complete through the beginning of December, representing over four months of information (Figure 6).

Figure 6

End-of-Semester Trackers

I also showed the class a temperature blanket that I knit for a different year (Shanti, 2018). It used a key similar to what we used for the weather trackers, with each row of the blanket having a color that corresponded to the daily maximum temperature for each day for our local location (Figure 7). I showed the class the blanket to suggest that, given more time together, we could get a fuller extent of the pattern of daily maximum temperatures and daily total precipitation over the course of a whole year.

Figure 7

Temperature Blanket

Two assignments served as final assessments for the weather tracker data visualizations and their connections to course content related to climate and seasons. The first involved finally identifying Mystery Locations 1 and 2, and the second was a portion of the final exam.

End-of-Semester Solving the Weather Tracker Mysteries Assignment

I provided each PST with an assignment that was a set of guided questions entitled “Solving the Weather Tracker Mysteries” coupled with resources available as links on our learning management system (Supplemental Resource B). The first question involved completing a graphic organizer using the Köppen Climate Zone resource (NOAA, 2023), documenting information about temperature, precipitation, latitude, and other information (e.g., proximity to mountains or the coast) for each of the six zones.

Next, PSTs were asked if Mystery Locations 1 and 2 were in the northern hemisphere and how they knew. In this way, PSTs were asked to share a claim and support it with evidence-based reasoning from the weather trackers. All PSTs claimed they were in the northern hemisphere and alluded to the cooling patterns across all three locations. For example, one PST responded, “Yes. They follow the same seasonal pattern of hot to cold” (PST #4). PSTs were then asked to order the locations in terms of latitude. All PSTs accurately placed Mystery Location 2 as having higher and Mystery Location 1 as having a lower latitude than our local area.

Then, I provided the PSTs with more Mystery 1 and Mystery 2 data that I had acquired from the NOWData website (NWS & NOAA, 2024), with location names redacted. These additional data were tables of (a) the monthly average temperatures for 2022 and 2023 and (b) the monthly total precipitation for 2022 and 2023, including the total annual precipitation for those years. From these tables, PSTs were asked to record for each location: the total annual precipitation for 2022, the *average* temperature of the coldest month in 2022 and 2023, and the *average* temperature of the warmest month in 2022 and 2023. The *average* temperatures were important to include since (a) we used maximum (not average) temperatures for our weather trackers and (b) the Köppen Climate Zones reference (NOAA, 2023) used temperature averages. I also provided PSTs with each location’s elevation and the distance to a large body of water.

Given this information, PSTs were asked to identify the Köppen Climate Zone for Mystery Location 1 and Mystery Location 2, providing reasoning as to how they knew. All PSTs now identified the correct climate zones for each location. Examples follow.

“[Mystery Location 1 is in a] tropical [climate] because it’s 6 feet above sea level and less than 10 miles from a large body of water. The precipitation and average temp is also the highest between the three [locations].” (PST #6)

"I think Mystery 2 is a moist continental mid-latitude climate due to the coolish summer but rapid change to winter [citing data from Köppen website and average temperature of coldest and hottest months]." (PST #8)

Towards the end of the assignment, I informed the PSTs that both mystery locations were in the contiguous US and asked for their best guesses as to what US states those were in. All identified Florida as Mystery Location 1, reasoning that it is the only state in the contiguous US that includes a Tropical climate zone. Mystery Location 2 was up for debate, with many PSTs identifying locations in the Midwest; this makes sense as there are multiple locations in the Midwest designated as Köppen Climate Zone D. Ultimately, in a final whole-class discussion, I shared the specific weather station locations for each mystery location.

Final Exam Assessment

On an open-book portion of their final exam, I asked the PSTs two questions related to the weather trackers. First, I asked: "What evidence did we gather and represent in our weather trackers to support the following claim: Both Mystery Location 1 and Mystery Location 2 are in the Northern Hemisphere." Three of the nine PSTs did not receive credit for their response because they did not provide answers using evidence from the weather trackers. The rest provided solid evidence and elaborated their responses beyond what they had provided in response to a similar question in their "Solving the Weather Tracker Mysteries" assignments. For example, on the assignment, PST #9 shared that "Yes, the temperatures demonstrate the season change that is occurring in the northern hemisphere." On the exam, they wrote:

"We noticed that the temperatures in both the mystery locations were decreasing, just like our local data. One location was much warmer than the other, but we know temperatures decrease or get cooler in the winter. When it is winter in the Northern Hemisphere, it's summer in the Southern Hemisphere, so with the decreasing temperatures, we knew both locations were in the Northern Hemisphere." (PST #9)

The other question was about the Köppen Climate Zone for Mystery Location 1 and how they knew. All PSTs accurately identified the zone as being Tropical and offered temperature and precipitation evidence; most included at least one more piece of evidence (e.g., latitude).

Discussion

One significant limitation of the visual representation provided by the trackers is that it depends on being able to distinguish among the colors of yarn. Those who are color blind may have difficulty finding value in the patterns in the trackers. One way to manage this would be to include the length of the yarn as another indicator. For example, red yarns could hang 30 cm from the dowel, and dark orange could hang 26 cm from the dowel, and so on.

Another limitation is that I did not assess their data literacy or data visualization literacy before and after the semester. I was able to observe PSTs translating tables of authentic data into the weather tracker data visualizations and then interpreting the patterns on those weather trackers as they connected weather patterns to broader ideas about climate and seasons. These are practices that others have suggested are likely to contribute to their data literacy (Bowen & Bartley, 2020; Kjelvik & Schultheis, 2019) and data visualization literacy (Börner et al., 2019; Gebre, 2018; Gebre & Polman, 2016), and practices that are in concert with aforementioned practices and crosscutting concepts in the NGSS (NGSS Lead States, 2013).

Additionally, our local station went down for a couple of weeks. I was able to reach out to the station through a contact, and shortly after, the station was online. We temporarily switched to another local station and corrected the yarn once the data was reported for the original local station. Although this presented a challenge, it was another opportunity for the PSTs to learn about the occasional messiness of working with authentic data (Bowen & Bartley, 2020).

As of this writing, I have started implementing a slightly revised version of this activity with another cohort of PSTs who are enrolled in my fall 2024 Earth-space science class. Thus far, we have added the August and most of the September 2024 data to our local and mystery location weather trackers. This set of mystery locations is different than the set I used last year. I will not reveal where they are for fear of this information becoming known to my PSTs prematurely. Soon, I will ask my PSTs how we can differentiate for those who are color blind (e.g., by altering yarn length). Also, I have asked those who add data to the local weather trackers look up data on the NOWData website (NWS & NOAA, 2024) instead of being handed a print-out. As the responsibility to track local data rotates across the groups in the class over the semester, all PSTs will have multiple opportunities to practice acquiring data from the website directly.

Conclusion

Overall, this activity allowed my PSTs to examine authentic weather data from three locations in the US, represent those data in a tactile data visualization, and observe patterns in the data throughout the semester. This enabled them to make arguments using those data visualizations about likely climate zones and latitude differences for those locations. The data was real, occasionally messy, and provided convincing evidence to support their arguments.

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