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Teachers as participant-narrators in authentic data stories

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ABSTRACT

This study describes outcomes from a place-based, teacher-scientist partnership intended to support teacher use of authentic data for science and math instruction. Teachers worked with scientists in the field to practice collection and analysis of authentic data. This case study investigated how narrative structure and contextualisation were created and used by teachers to convey meaning from the scientists to students. Participant interviews, focus groups, and researcher notes were qualitatively analysed through production and testing of propositions. The results show that teacher narratives were based heavily on the scientists' narratives as informed by teachers' own field experiences and authentic data. Teachers served as participant-narrators in the narratives rather than central agents, and they used the elements of narrative structure to frame knowledge that is co-constructed by the scientists, teachers, and students. This model of transfer through story is described in detail along with implications for research and practice.

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Preliterate humans used story structures such as narrative and setting as tools to maintain fidelity of communicated information (Wolf, 2007). We remember our experiences in the form of non-fiction stories with attached meaning and declarative knowledge (Schacter, 1996). We use the term 'story' in this way throughout this article. While story remains an important teaching tool in modern societies, there is a tension in using story for teaching science (Avraamidou & Osborne, 2009). We argue that story can play a useful role for helping learners understand science practice as well as the natural phenomena that are central to science.

We present the case of a place-based, teacher-scientist partnership project (TSP; Shein & Tsai, 2015) to examine the ways teachers used elements of story to situate science knowledge and then bring that back to their students. Specifically, we were interested in how teachers developed a sense of their own story in which they became agents through participation in the TSP. The authors facilitated an ongoing TSP to help teachers, and thereby their students, learn how to view authentic data as situated within interdependent natural phenomena. Through the Numbers in Nature project, teachers worked with scientists at two field sites to collect and examine data, and co-develop science and math curriculum built around the authentic data.

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Narrative as a mechanism for contextualisation

Contextualisation is the degree to which subject knowledge is connected to the world beyond the classroom (Giamellaro, 2014; Gilbert, Bulte, & Pilot, 2011; King & Ritchie, 2013). Contextualisation can be perceived as the framing of a curriculum or instruction within a real or imagined context as well as the way in which any actor comes to connect content knowledge with real contexts. Contextualised curriculum is associated with large effects on student engagement (Potvin & Hasni, 2014; Ward et al., 2016) and small to moderate effects on comprehension of science content (Bellocchi, King, & Ritchie, 2016; Gilbert, 2006).

Giamellaro (2014) proposed a key distinction in how contextualisation is utilised in education: students can learn *in context* (*primary contextualisation*) or *with context* (*secondary contextualisation*). Primary contextualisation involves the learner being immersed in the context, such as field studies and internships. Secondary contextualisation refers to students having access to second-hand accounts of context, such as narrative text, documentary film, or role play. Through primary contextualisation, one becomes part of a story while one receives a story through secondary contextualisation. In the current study, we examined the weaving in and out of primary and secondary contextualisation as the scientists shared their own experiences with teachers (secondary), as scientists and teachers shared an experience in a context authentic to the science (primary), and as teachers then shared that experience with their own students (secondary).

As with contextualisation, one goal of storytelling is to situate important ideas into a narrative structure that is understandable and relatable. Narrative structure gives meaning to individual events by showing how they are connected to the whole (Norris, Guilbert, Smith, Hakimelahi, & Phillips, 2005), as contextualisation does for the learner. Paris and Mercer (2002) proposed that there are three ways one can connect to a story through narrative structure: autobiographically, vicariously, or through shared social experiences and values. Most stories are experienced vicariously and the narrator has a critical role of determining the purpose by choosing the events and the order in which they are related, filtering information (Metz, Klassen, McMillan, Clough, & Olson, 2007) and assigning meaning (Norris et al., 2005). Because 'narrative gives priority to the stories that connect people with objects and events' (Paris & Mercer, 2002, p. 406), story provides a mechanism to connect primary and secondary contextualisation as a learner incorporates others' experiences into their own (Giamellaro, 2017). We propose that story might be a tool to align how scientists, teachers, and students contextualise knowledge, particularly if teachers become personally embedded in those stories. We examine how the teachers vicariously adopted aspects of scientists' stories, became part of shared stories, and then vicariously shared these amalgamated stories with their students.

Narrative and science learning

Bruner (1986) describes story as one of two primary ways of thinking and knowing, contrasting it with a logical, argumentation-based way of knowing. Because stories closely correspond to lived experience, and because they parallel the way we make sense of the world (Gough, 1993), they are easier to comprehend than other modes of communicating information (Avraamidou & Osborne, 2009). Story involves the recipients personally and must predict recipients' points of common experience if it is going to be successful (Avraamidou & Osborne, 2009). Characters' actions are a sequence of related events (Metz et al., 2007) and story includes the elements of *narrative appetite*, *structure*, *agency*, and *purpose* (Norris et al., 2005) to share meaning between people (Bruner, 1986).

Bruner's cognitive theory (1986) highlights the tension between the scientific/argument-based way of knowing as the contrast of the storied way of knowing. In Bruner's conception, argument uses empiricism to convince of universal truth where story seeks verisimilitude. Agency creates an additional tension between narrative and scientific structure. Narrative requires that there is an agent who affects or is affected by some other force. However, science is often focused on correlation, which need not include an agentic force. Avraamidou and Osborne (2009) argue that agency can be interpreted or implied within natural phenomena, as in the cases of air pressure impacting other systems or a water droplet dispersing light. Cause and effect as well as systemic relationships are functionally similar to agency in the human consciousness and can serve the same function within narratives.

One approach to using narrative in science teaching is the use of historical accounts of past scientists (Milne, 1998). While this approach has been associated with both benefits and problems (Metz et al., 2007), it is limited to uncovering the practices and sociocultural context of science rather than the core science function of explaining natural phenomena. Norris et al. (2005) introduce a useful distinction between this type of process-oriented explanation of what happens within science, or *extrinsic explanations*, from those that explain the natural phenomena themselves, *intrinsic explanations*. While not a perfect parallel, one could think of intrinsic explanations as some combination of the Disciplinary Core Ideas and Crosscutting Concepts undergirding the Next Generation Science Standards in the U.S. and extrinsic explanations as some combination of the Science and Engineering practices with the socio-cultural, historic activity of science.

While good stories and good arguments are judged by different criteria, Bruner (1986) suggests they are complementary. We adopted this stance and sought to examine how stories and arguments could complement each other as teachers sought to learn, process, and teach content knowledge they learned from cooperating scientists. Within the context of this study, teachers were positioned to consider their own developing stories and explanations, those of the scientists, those that were co-constructed, and then synthesise these into science content to be shared with their students. We sought to track these stories, to examine how intrinsic and extrinsic explanations were woven into situated practices of the teachers and scientists, as well as their lived stories.

Methods

We used an exploratory, phenomenological, qualitative case study approach to analyse teacher experiences with the place-based TSP project. We asked several analytic questions to better understand those experiences,

(1) Did teachers develop a sense of story via their participation in the place-based teacher-scientist partnership? and if so,
(2) Did teachers identify as agents in those stories?

(3) Which story elements did teachers use when discussing their experience?
(4) How did teachers use story to transfer knowledge and practice from the scientists to the students?

Using a variety of qualitative data to examine the use of story from a participant (emic) and a researcher (etic) perspective, we explored the way story drove and emerged from teacher experiences.

Participants and context

The case was built from teacher interviews, and researcher field notes. Thirty-three math, science, and elementary teacher participants from public schools in the Western U.S. were recruited via email. During the first summer, teachers travelled to a forest research station for a four-day retreat with direct instruction on contextualised learning, modelling, and field teaching methods. Participating scientists gave overviews of their research and led field excursions to demonstrate how they collect their data (Figure 1). The teachers and scientists also worked extensively in small groups to develop grade-level curriculum using authentic data to address state standards. Throughout the four days, teachers and scientists lived, ate, and socialised together. The HJ Andrews Experimental Forest is a watershed-scale forest jointly run by the Oregon State University and the U.S. Forest Service. Research is conducted in forestry, ecology, hydrology, wildlife biology, and myriad other disciplines. Contemporary data can be compared to seventy years of data that document change over time for the ecosystems within the watershed. For this project we worked with an ecologist, soil scientist, forester, and two hydrologists.

Throughout the subsequent fall semester, the teachers tried their new curricula in their classrooms, shared the data and vicarious experiences with their students, and participated in videoconferences with the scientists to clarify or modify the curricula. Following the retreat, teachers and scientists reconnected via videoconference sessions. During the subsequent winter, teachers attended a second retreat at Mt. Bachelor with a new group of scientists. The Mt. Bachelor Observatory is an atmospheric chemistry research site at the top of a mountain with access to atmospheric currents. Mt. Bachelor is also a ski resort with lifts that provide access to the observatory and to the snowpack at various altitudes and exposures. Teachers again went out into the field to contextualise data collection and repeated the curriculum development and enactment process with the support of the scientists. For this site we worked with an atmospheric chemist, hydrologist, ski patrollers, and a computer scientist developing avalanche detection technology.

A final one-day retreat in the spring allowed the group to consider next steps and collectively reflect on the project. All participants received a modest stipend. Please see Giamellaro and O'Connell (2018) for a more detailed discussion of the project structure and teacher outcomes.

Data collection

Data were collected from: (1) researcher notes, (2) teacher focus groups, and (3) individual teacher interviews. The researcher notes are written reflections captured during and shortly after each project event, representing the observer (etic) perspective. Through

Figure 1. Visual examples of teacher experiences in the place-based TSP. From top, left and clockwise: Participants test stream chemistry, calculate snow-water equivalent, measure stream discharge, and analyse snow crystal structure.

these notes and the process of phenomenological bracketing (Grbich, 2013) the role of narrative emerged as an important phenomenon for teachers. At the conclusion of the study, all teachers participated in 45-minute focus group interviews in which they responded to six prompts about their experience with the project, outcomes, barriers, and specifics about interactions with the scientists. While teachers were not explicitly asked about narrative or contextualisation, we used their responses to identify when these characteristics were important to their experience (Brenner, 2006). Similarly, 13 teachers were interviewed (all were invited, 13 were able to) with a structured protocol of seven questions regarding impact on their knowledge, practices, and students' outcomes. Focus groups and interviews were recorded and transcribed verbatim.

Data analysis

In a first round of coding, one coder (first author) applied *concept codes* drawn from existing research on narrative and contextualisation (Appendix). Miles, Huberman, and Saldana (2019) describe concept codes as having 'meso or macro levels of meaning' (p. 66), often identifying processes, and as applied to stanzas or larger passages of text that 'harmonize with the bigger picture suggested by a context' (p. 66). The data were excerpted in conjunction with these concept codes in order to capture these complete concepts while retaining as parsimonious an excerpt as possible. The search for abstract principles within the emerging phenomenon used these codes as a starting point (Grbich, 2013).

To achieve *phenomenological reduction* (Grbich, 2013), we used an analytical technique described by Miles et al. (2019) in which the researcher generates propositions from their own thinking about patterns in collected data and then tests the statements against the actual data. In other words, the propositions are tools rather than results themselves. As an exploratory study, we generated *etic propositions* from researcher notes and tested them against the available data. In two instances, new propositions were identified within the participant responses that had not been identified in researcher notes. We distinguish these as the *emic propositions*. To test these propositions, concept code frequencies (Figure 2) were first used to indicate how often themes associated with contextualisation and narrative/story were discussed by participants. Code co-occurrences (Figure 2), and other patterns were then used to support or contradict the propositions. We then examined the text of the participant perspectives to determine how they were experiencing the elements of story and to search for interpretations that rivalled the original propositions (Miles et al., 2019). The propositions that were supported by data from multiple participants and not substantially contradicted by other participants' experiences were developed into assertions that connect these results to themes beyond the study and that could readily serve as hypotheses for future testing (Miles et al., 2019). The propositions that were not supported by subsequent participant data also informed the resulting assertions by suggesting ways in which teachers were not interacting with story in the ways anticipated by existing research and the researchers' early observations.

Results

The analysis described above led to three etic and two emic propositions regarding how teachers used elements of story in their learning and subsequent teaching. Table 1 summarises these propositions and lists whether each proposition was supported by the participant data. The remainder of this subsection describes the sourcing, evolution, and disposition of each of these propositions. Table 1 also shows which propositions contributed to the inferential assertions described at the end of this section.

	Total code frequency	Secondary Contextualization	Extrinsic Explanation	Intrinsic Explanation	Narrative Explanation	Agency	Events	Narrative Appetite	Narrator	Purpose	Receiver	Setting	Structure
Primary Contextualization	**65**	26	38	16	19	50	48	39	47	49	35	38	42
Secondary Contextualization	**81**		42	24	17	50	29	43	55	55	52	22	39
Extrinsic Explanation	**84**			18	15	57	40	44	59	59	44	25	41
Intrinsic Explanation	**39**				6	23	16	20	26	28	21	11	19
Narrative Explanation	**31**					26	21	22	25	22	19	14	20
Agency	**97**						59	61	80	75	62	39	58
Events	**70**							43	52	53	38	37	44
Narrative Appetite	**76**								58	62	47	34	51
Narrator	**101**									77	77	37	55
Purpose	**99**										62	37	59
Receiver	**83**											29	43
Setting	**46**												36
Structure	**69**												

Figure 2. Concept code frequency and co-occurrence. Concept codes represented central ideas in contextualisation and narrative. Codes were applied to excerpts within all transcripts. Cells are coloured by distribution (red = lower quartile, yellow = median, Green = top quartile). Top quartile frequencies or co-occurrences indicate that these themes or combinations of themes regularly occurred throughout participant responses. Code counts and co-occurrences were used as an intermediary step to suggest where patterns needed to be further examined in the narrative responses. (Colour online).

Table 1. Sources and status of the analytic propositions and connection to summary assertions.

	Proposition	Source[a]	Supported?
1	Teachers connected phenomena to place	etic	No
2	Extrinsic explanations were more important than intrinsic explanations to teachers	emic	Yes
3	Teachers conceptually accessed the science and data via personal connections to the scientists	etic	Yes
4	Teachers struggled with bringing authentic data back to their classrooms but were more likely to do so when data were contextualised	etic	Partially
5	Narrative Elements of Story Worked Together to Positive Effect	emic	Yes

[a]Etic propositions were sourced from early researcher observations and existing research. Emic propositions emerged from early participant data.

Proposition 1, teachers connected phenomena to place

The first proposition captures the idea that teachers were associating specific scientific concepts with specific places in the field. Though researchers observed this phenomenon in the field and it was expected based on existing research, the proposition was not supported by the longitudinal participant data. When teachers discussed the physical setting as important elements of the story, it was typically a place where they brought their own students to conduct field work and even then, action was privileged over the phenomena being explored.

The discrepancy between etic and emic perspectives with this proposition may be explained by the timing of the data collection. The researcher notes, which indicated frequent and specific connections to place, were largely captured during the field retreats and in early conversations with participants while the interviews and focus groups occurred at the end of the study and were reflective in nature. Even if the connections between place and phenomena appeared important when teachers were first exposed to the ideas, those connections were not maintained as important in the long-term.

Proposition 2, extrinsic explanations were more important than intrinsic explanations to teachers

The etic/emic discrepancy with Proposition 1 also led to the recognition of a new proposition within the patterns of teacher reflection. Proposition 2 suggests that teachers were more focused on the socio-cultural, historic (extrinsic) aspects associated with explanations for phenomena than on the explanations of the phenomena themselves (intrinsic). In describing the part of the project that was most valuable to him, a high school math and science teacher said,

> For me it was working, hearing their (scientists') stories and seeing their methods and thinking what went into their research questions and their scientific method that they were doing. I think just hearing their story and their perspective, and talking with them one on one, I was able to sustain more understanding of how they use their data and how they sift through it and find useful data sets. That was big. What was big for me was just talking with them about, "Where did it come from and how did you get it to that usable form?" And, see them actually work with spreadsheets with Excel and just see some of the work they were doing.

For this teacher and others, the value was in seeing the process rather than the outcomes of science and the goal was to bring those practices back to his students. A middle school science teacher also described how the patterned ways of thinking she developed through the project became a part of her teaching practice,

> I find that everything we do, we're collecting data now. Kids are inputting things into Google sheets and we're looking at it together. We won't just collect data in one class, we'll collect data in all the classes and go back the next day and look at it. We've had some really powerful argument-driven inquiry-type projects where the kids have collected their own very complex data. Looking at it, the different lenses that they were looking at their data, told different stories so they had to make decisions. It's just been a year of data.

Interacting with the scientists, observing how they approached even the mundane tasks of data analysis, and doing it with them helped these teachers to see how they could bring these practices into their classroom. However, this was not an automatic outcome. In the following focus group exchange two elementary teachers explain where this broke down for them,

> Teacher 1: How would you be able to use this to foresee avalanches or collect data? But I ran into the same thing. I'm like, "I don't know what to do with this now."
> Teacher 2: Even if I did collect it, I didn't know … "Okay well what story is this data really telling? How are we presenting it? How are we interpreting it?" … So, we've done this, but what now? What's the next step?"

In other cases, the teachers may have been overly focused on the extrinsic explanations to the point where the intrinsic explanation was lost, as exemplified in this high school science teacher quote,

> We did the fish migration one (dataset), where it had the years for 50 some years and all these data points. I think I'm gonna assign each group a year, and then look at the months and then compare the graphs from each group. I think that would work better than, "Here's all this data. Go with it."

In this scenario, the ecologist provided a dataset showing salmon spawning runs to a creek over time. When examined together, the data tell the story of climate change as the return dates trend earlier. Any given year is unremarkable. Thus, the intrinsic explanation was lost but even the extrinsic explanation was not communicated with fidelity. This pattern was more common with the elementary teachers whose background knowledge did not necessarily prepare them with foundational intrinsic scientific explanations.

While teachers did not focus on the intrinsic explanations as often as they focused on extrinsic explanations, there were cases when the codes co-occurred, leading to further analysis. In most of these cases the teachers described nuanced descriptions of how they came to understand an idea or how the combination had helped their students to do so. In all of these cases, the extrinsic helped to develop the intrinsic or spurred a need to know, as described here,

> That next step that the conclusions that they're making from the data and representing visually, you can kind of see some patterns but what is the … What does that connect to and why is it important? That contextualization bit for sure with the carbon fixing or through the carbon kind of being delivered to the ocean. What's the big picture? Kind of add in so why would we even look at a stream transporting carbon in the first place and kind of bring that in, rounding out the story and that of course it's important because it ends up in the ocean and the ocean is our kind of fixer of carbon dioxide or carbon monoxide or all carbon I suppose. It kind of is that connector piece of … here are some numbers but why are the numbers important?

Across the range of participants, engaging in extrinsic explanation alongside the scientists resonated with the teachers, inspired them, and seemed to have the most impactful inroads into classroom practice. This proposition, that extrinsic explanations were more important to teachers than intrinsic explanations, was well supported by the data though the inclusion of both led to reports of the most impactful learning scenarios.

Proposition 3, teachers conceptually accessed the science and data via personal connections to the scientists

Proposition 3 suggests that the teachers relied on the scientists as a reliable source of authentic data and supporting contextual information. Researcher notes suggested that teachers were making choices about which data and concepts to use as a function of their interactions with the specific scientists, at least in part. The teachers' reflections supported this proposition. Teachers recognised the scientists as a reliable source of targeted information. By knowing the scientist, they were confident that they could find the right information, as noted by a middle school math teacher, 'because I had access to those scientists I've got like, oh, there's that more powerful data set. Here's where I can get more data.' A high school science teacher wrote,

> Working with [atmospheric chemist] in getting air pollution data, and I'm blanking on the actual resource right now but just this amazing website where you can go into any city that has air pollution data and will pull data for years back on a number of different variables.

Once the scientists had endorsed a resource, such as a website, the teachers felt a sense of relief to know that it was credible, useful and relevant.

Teachers worked with all of the scientists for an introduction and then focused their curriculum development work with one or two. The goal was to pair up based on an alignment of grade level standards and scientist expertise.

> Obviously, [soil scientist] worked really well with us, because a lot of our stuff is based around soil. Same thing, [hydrologist], same thing because we got a lot of snow pack stuff. I think taking scientists that really match to our standards was very helpful for us at the elementary level, because we do have a wide variety.

In practice, the teachers seemed to more often align themselves with the scientists who could best explain the science to them. Interestingly, all of the scientists were described as the best at this by a few teachers, even when other teachers had described the same scientists as struggling to communicate with them. A middle school science teacher explained this decision process,

> I think a barrier for us probably at first was I felt overwhelmed by the data sets like [ecologist 1] and [ecologist 2]. For me, I found their work to be the most interesting but their data to be the least approachable for me to interpret that for the kids. [hydrologist], his work really spoke to us and we were able to glom on a little bit to him.

It should be clarified that the teachers held a deep regard for all the scientists, reported in phrases typified by, 'they're such amazing people … human beings, but also just so knowledgeable and skilled.' When pairing for curriculum development, teachers did not seem to be aligning to scientists of particular gender, race, or other homophily. Rather, the teachers seemed keenly aware of their own level of understanding, gaps in their understanding, and the contexts of their own classrooms. The scientists were sources of information for their classroom practices but that access was also contingent on the scientists' ability to understand the context of a given teacher's classroom.

Proposition 4, teachers struggled with bringing authentic data back to their classrooms but were more likely to do so when data were contextualised

In the proposition 3 section teachers described scientist connections as an access point to useful data. Proposition 4 suggests a somewhat opposing phenomenon in which teachers found it difficult to bring the scientists' data back to their classrooms, though their contextualised understanding mediated that to some degree. Teachers described struggles with using the data in their classes, as described by one high school math teacher,

> For myself that was a struggle with me with using the data from the scientists because I was barely understanding what was happening … I didn't feel comfortable coming up with things from it, being able to extract what was happening in that graph and I didn't want to bring it in and not be able to help them through it.

This teacher was able to interpret the syntax but not the meaning from the graphs- the data but not the story. A project goal was to help teachers develop extrinsic skills and clarify intrinsic explanations through first-hand experience of the phenomena. In our researcher notes we recorded numerous examples of teachers expressing understanding of the targeted natural phenomena when they were measuring and observing at the field sites. Teachers were inspired by the primary contextualisation experiences as captured here, 'it was super powerful for us to experience that with them (the scientists) and our excitement we can pass on to our kids. Just being out there with the scientists was really super fun and exciting.' In some cases, teachers also reported that this was useful for their teaching, as in this elementary teachers' thoughts,

> I think without the context that they brought it would have been kind of a moot point … I wouldn't have remembered, and did I love tromping around in the snow? No, I did not, but did it bring me a lot of context that I could then bring to my children? Yes, it did. In that case it was really great.

However, the interview data suggest that while these field experiences helped with teacher interest and contextualisation, they were not often applied to bringing data back to the classroom. Several teachers struggled making the relevance of their own experience also relevant to their students. Two middle school science teachers shared their thoughts on this disconnect,

> Teacher 1: I just didn't think it would be that engaging for my kids to say, "Hey, I went to this place, and this is the stuff I got." To me that doesn't feel close enough to them.
>
> Teacher 2: With the avalanche data with the sounds, it was a great hook to use when teaching my waves unit, but I wasn't able to pass that off to the students as easily as I would've liked. Obviously, I get excited about avalanches and talking about these things but they were not as jazzed about it as I was, so tough sell.

While they inspired the teachers, the field experiences did not seem to directly result in a mechanism for teachers to bring data back to the classroom. Teachers did report bringing pre-interpreted data to the classroom in the form of scientists' stories. Teachers brought relevance and framing for content. For example,

> When we (her class) went to our local stream here and found the discharge rate, and the snow depth, and the temperature, then to show them that we could go online and go up to the [local] Mountains and look at those same facts, and tie that in to, "This is real. You are doing what real scientists do." (elementary teacher)

Several teachers described scientist experiences/stories as a way to drive student interest that could carry a unit. The scientists' experiences/stories seemed to be packaged in a way that the teachers felt garnered more credibility than teacher field experiences. An elementary teacher reported value in the project videos, saying, 'they (students) love seeing the video that they gave us from the [forest]. They sort of understood the data, to see the pictures of "wow there's that many landslides up there?" "Wow, I had no idea."'

While the scientists' stories seemed to be a more common vehicle for getting the scientific content and data into the classroom than were teachers' own stories, the teachers' field experiences may have played a role in how they came to understand scientists' stories. This understanding, in turn, was reported to impact delivery and framing of content in the classroom, as explained by a high school science teacher,

> One big take away for me was … being able to ask the scientist why does the dataset matter and really, I noticed a big difference between my fall segment I did and my spring segment I did. In my fall segment I had a lot more confidence in why it mattered and was able to communicate that to my students a lot more just because I had the background information I had. With the additional information I had a really good story and the buy-in from my students in the fall was way bigger and then I just didn't have that for my spring project quite as much and even though it was a way more hot topic, my students didn't grab onto it.

The 'background information' of 'why it mattered' was developed during the retreat and through working with multiple scientists. This teacher had used this experience to support and understand the 'story' behind the data shared by the scientists, enough that she felt confident to use the authentic data effectively.

Teachers reported the use of scientists' stories (secondary contextualisation) being used in conjunction with their own field experiences or those they prepared for their students (primary contextualisation). They discussed the combination of primary and secondary contextualisation as being effective at encompassing both personal relevance and accessibility for the students while maintaining a connection to the bigger picture shared by the scientists. A middle school science teacher shared how this played out in her class as she wove the two levels of contextualisation together and used authentic data,

> We went in the field in the fall to the [Local River] and the big question was "is this river healthy for salmon and trout?" You could see 'em spawning so that was exciting for the kids to see them spawning while we're there and then that the water from that river all comes from an aquifer and we watched it come out of the ground. Where does that water come from? We talked about snow and that was in October. In January … we did the dam and the sockeye salmon data set and they graphed it and we introduced correlation and line of best fit that day and they were learning about slope in their math classes … in my last activity, I took that data and we did SNOTEL (SNOpack TELemetry) data and they looked at May SNOTEL data for [data recording station], which is sorta the watershed that drains to the [Local River] and they looked at how much water's in the snow in May, May 1st. They looked at historical May 1st data, and you could see that it was really different and so they grabbed some stuff. They did kind of get more excited because they remembered the fish thing we did and then they remembered our field trip they saw the fish. They could put it together but that helped having a connection between all the things we did versus just, "oh and here's another thing on snow nothing to do with anything."

Another middle school science teacher described how visualisations (data stories) shared by scientists were useful to her as she prepared curriculum, even if they were not shared directly with the students. The balance between primary and secondary sources of data was explored by many of the teachers. They wanted students to use the authentic data from the scientists when they were accessible to students (i.e. 'cleaned') and they wanted students to collect their own authentic data. Each came with its attendant frustrations and barriers.

Overall, when teachers had practice collecting and interpreting data with the scientists, worked with them to design curriculum that was likely to result in manageable data, and used those experiences to lead students through the process, they reported successes. When either the secondary or the primary contextualisation was missing, teachers reported less encouraging results with student learning. Even though teachers did not report bringing their own field experiences into the classroom, some provided field experiences for their students modelled on their own and that thereby mesh with the work of science professionals.

We found this proposition to be partially supported. Teachers did struggle with bringing the data back to their classrooms and this was mitigated by contextualisation. However, teachers' primary contextualisation experiences seemed to produce only indirect effects on the use of data in the classroom. The scientists' data, in story form, seemed to provide a more direct vehicle for bringing the content into classrooms, albeit informed by the teachers' experiences with them.

Proposition 5, narrative elements of story worked together to positive effect

Proposition 5 describes teachers' use of narrative story elements not in isolation but as a wholistic set. In applying concept codes to the data, two trends emerged in the application of the story element sub-codes. First, when one element of story was present, it was likely that multiple others were as well. *Agency, narrator*, and *purpose* were the most likely to co-occur with the other elements of story. A second trend was a qualitative correlation between the number of the story elements and the degree to which teachers spoke of those experiences as positively impactful for them or their students. As one example, we can parse out the quote above in which the teacher outlines the story of bringing her students to the river. The following narrative elements can be identified as the details are woven into the form of a story:

Agency:	Extrinsically, the teacher, students, and people behind the data. Intrinsically, the fish arguably have some agency.
Events:	Visit to the river, "we did the sockeye salmon data", "we did … ", "we looked." Classroom activities.
Narrative Appetite:	"where does that water come from?" "Is the river healthy for salmon?"
Narrator:	The teacher, possibly the students by the end.
Receiver:	Students, general public.
Purpose:	To answer the questions about fish, snow, water correlations.
Setting(s):	Local river, classroom, SNOTEL data collection site.
Structure:	The story builds from the early experience at the river and foreshadows the use of data later in the year. At the end, students bring together the observations, the fish data, snow data, river data for a conclusion.

There were 15 excerpts in which the full array of narrative elements was present and these were all associated with positive experiences. It is not clear if these were perceived as positive because the elements were all there, if the positive experience led to the recognition of all of the narrative elements, if this was coincidence, or if there is another explanation.

When *narrator* and *receiver* co-occurred without the other narrative elements, the accounts were often negative in tone. This pattern often captured a discordance between the narrator and receiver, as captured succinctly by an elementary teacher, 'I think some of us elementary teachers were like, 'that was Greek.'' The isolation of narrator and receiver also implies a lack of contextualisation. Across the teacher accounts, there is support for the proposition that the narrative elements compound to positive effect.

From propositions to assertions

Through testing the propositions against the interview and focus group data, we developed three assertions to 'synthesize a vast number of individual analytic observations' and build toward 'higher level interpretations about the meaning of the study' (Miles et al., 2019, p. 93). Given the degree to which the five propositions were supported, we assert the following as:

(1) Teachers in a place-based TSP drew heavily from the stories of the partner scientists, which include intrinsic and extrinsic scientific explanations as well as reference to authentic data. (*Propositions 1,3,4*).
(2) These stories, shared through secondary contextualisation, were supplemented by teachers' own field experiences. (*Propositions 3,4*).
(3) Using narrative structure, teachers condensed and filtered these experiences into a story focused on extrinsic explanation, shared with students through secondary contextualisation, and robustly supported by students' field experiences. (*Propositions 1,2,5*).

Taken together, these assertions outline the process that teachers used to share content knowledge and practices between the scientists and their own students. This process is diagrammed in Figure 3. These assertions offer the potential for future research in which they can serve as hypotheses for more targeted investigation.

Discussion

In the subsequent sections, we further describe the assertions, link them to previous research, unpack the process outlined in Figure 3, and discuss implications of the study.

Developing a sense of story

Our first analytic question asked whether teachers develop a sense of story via their participation in the place-based TSP. Teachers did develop a sense of story through the experience and in so doing, the stories helped align how the scientists, teachers, and students situated knowledge. Teachers used these stories to carry the experiences of the scientists to the students and to capture elements of verisimilitude and connection between events, as Bruner theorised (1986). As researchers, we had implicitly asked the teachers to share knowledge between scientists and students and they used the devices of story to do so, capturing the 'human and human-like intention and action and the vicissitudes and consequences that mark their course' (Bruner, 1986, p. 13). This focus on the human

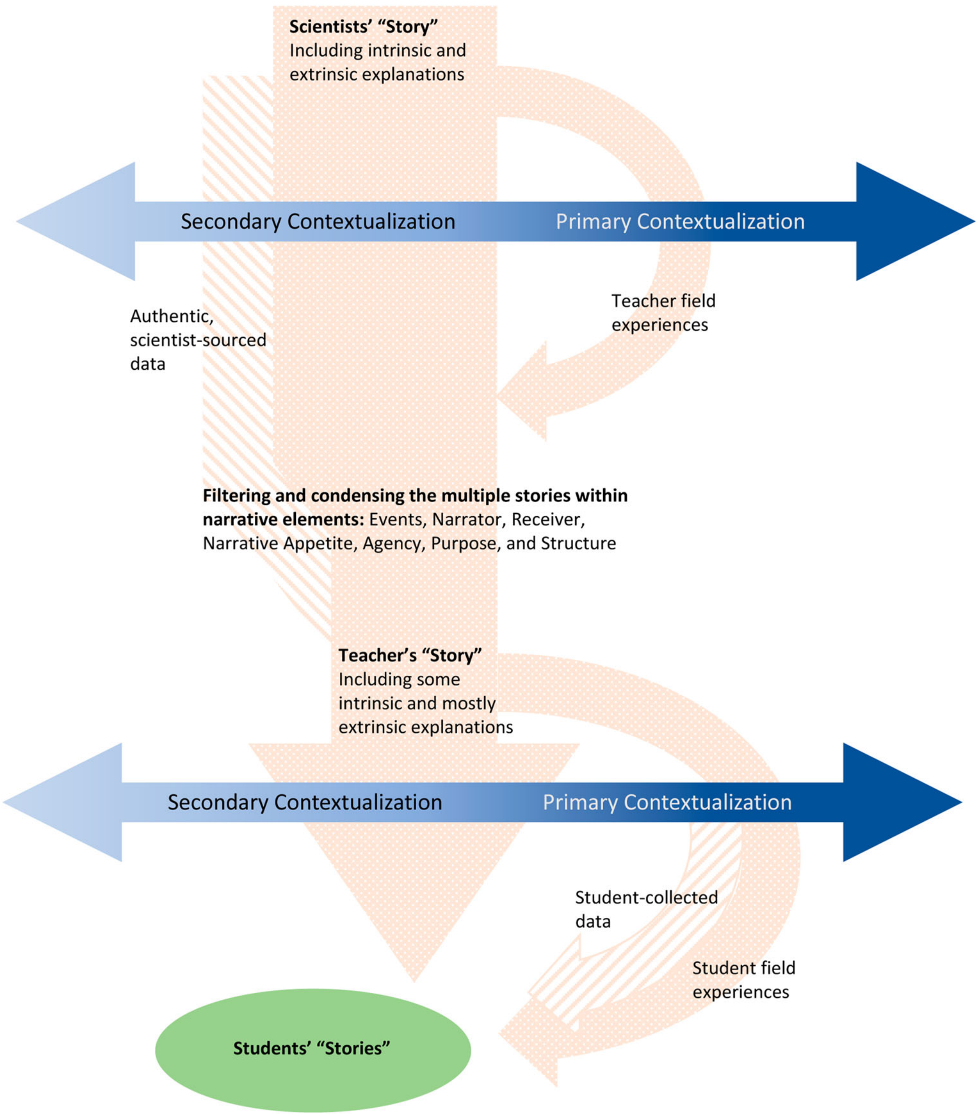

Figure 3. Teachers' process of collecting, developing, and sharing instructional stories. The diagram tracks the flow of scientific explanation from top to bottom. In the study, teachers relied heavily on scientists' information as secondary contextualisation. Teachers also considered some authentic data from the scientists. Teachers' primary contextualisation field experiences contributed to their understanding but did not become central elements in their stories. Teachers organised all this information in narrative structure, at times creating student field experiences to similarly support but not drive instruction focused on secondary contextualisation, largely sourced from scientists' 'stories'.

element of the stories is a likely explanation for the contrast between proposition 1, which was unsupported, and propositions 2 and 3, which were supported. Teachers were inspired not by the practices themselves but by the scientists who modelled the extrinsic explanations. Although teachers were also inspired by the settings where the stories took place, setting became secondary to the human action that is inherently central to narrative structure (Norris et al., 2005). Teachers were not asked to develop a story but it became a natural mechanism for them to situate and synthesise a vast amount of information.

One result of this storied rather than argumentative organisation of knowledge (Bruner, 1986) is that it favoured extrinsic over intrinsic explanations. This was exacerbated by the retrodictive nature of story (Norris et al., 2005) in that the information was shared from scientists to students via the teachers as historic occurrences without a need for the predictive power of intrinsic explanation. However, when teachers did incorporate both extrinsic and intrinsic explanations, they described these events as powerful learning experiences in which students could think across temporal scales, different settings, and shifting agency. Future research that intentionally combines storied and argumentative ways of knowing, intrinsic and extrinsic explanations, could explore the degree to which these positive outcomes can be leveraged.

As storytellers, the teachers were in a complex position as they received others' stories, lived their own stories and then tried to package those into revised stories for their own students. In doing so, they needed to readily transition back and forth between different contexts, and different times, both real and abstract. They needed to regularly convert between primary and secondary contextualisation (Giamellaro, 2014) as learners and teachers. Seemingly to preserve the contextualised nature of the knowledge and to mitigate student struggle with 'fluid transitions' between contexts and concepts (King & Ritchie, 2013), the teachers used story to carry as much of the contextualisation as possible across the transitions from person to person. Teachers' use of datasets was an illustration of this concept. The teachers worked with the datasets alongside the scientists, a primary contextualisation experience. Most teachers who carried this experience forward to their students did so as either a conclusion drawn from the data, a data story, or as an example of the work scientists do. The data story rather than the dataset was used to carry the information.

Teachers as agents in the stories and primary contextualisation

Our second analytic question asked if teachers identify as agents in the developed stories. The simple answer is 'no', they rarely took an autobiographical stance (Paris & Mercer, 2002) or brought in their own field experiences when discussing the work with their students. However, the data suggested a more nuanced explanation, that teachers saw themselves as part of the story, just not the central part of the story around which it should be built. Teachers took on the critical role of narrators and in this way demonstrated agency within the narrative. Rather than serving as the central agents, they were the *participant-narrators*, both relating a second-hand story they were present to witness, and bringing the receivers actively into the story. The teachers connected students to an expansive practice beyond the classroom, beyond the teacher. In connecting students to this broader context, they likely impacted student engagement as well as their depth of conceptual understanding (Ward et al., 2016).

The storyteller or narrator has a critical role of determining the purpose by filtering the information being shared (Metz et al., 2007) and gives meaning to the story through these choices (Norris et al., 2005). As teachers were making choices about how to frame data stories, even if implicitly, they were considering the recipients. Teachers explained their own successes and struggles with receiving the scientists' stories and reported cogent decisions about how to reframe those stories so they would be maximally accessible to their students. Such prediction of recipients' common point of experience is crucial for a sense of personal involvement in a story (Avraamidou & Osborne, 2009). Meaning is connected to the agents in a story and to the recipients of it (Metz et al., 2007). Rather than positioning their own experiences as central, teachers attached meaning to the scientists and their students.

Narrative elements in the stories

Our third analytic question asked which story elements teachers used when discussing their experience with the place-based TSP. Teachers were more apt to focus on the agents within the story, than on the setting or the specific events. This changed slightly when the teachers included their own students in the story (student stories, Figure 3) through primary contextualisation experiences. Purpose was also a central narrative element as teachers used the stories to share meaning across time and place (Norris et al., 2005). The individual events were only important insomuch as they were connected to the whole and juxtaposed against the perspective of other events (Norris et al., 2005). Teachers reported that their intentions in using story elements were to make content relatable, easier to comprehend, and aligned to human experience (Norris et al., 2005). They used narrative structure with the implicit goal of secondary contextualisation (Giamellaro, 2014).

Because stories have a structure that allows us to understand the world in which we live (Gough, 1993), teachers seemed to be using these structures to make sense of the natural world from the perspective of the scientists. This sense-making seemed most present when the complete complement of narrative elements was present, suggesting that a narrative teaching approach is most effective when teachers are supported to incorporate all of the narrative elements. In contrast, when only narrator and receiver were described by teachers, in the absence of the other contextualising narrative elements, the effect seemed to be negative. In other words, full narrative structure seems to be more than beneficial, it may be required.

Within this narrative structure, some of the original meaning was lost, however. Although the scientists were ultimately interested in the phenomena, the intrinsic explanations, the teachers' stories tended to share the extrinsic explanations. This may have been a function of the narrative structure, in that meaning must be constructed by the receiver of the story. The scientists could share the *how*, relying on the implied meaning. When the teachers shared the filtered and condensed stories with their students, some of that meaning was no longer implied and might have been lost altogether. This reflects Bruner's (1986) claim that story and argument can complement each other but cannot be conflated. In the process of carrying knowledge from the scientists to their students, teachers relied on storied ways of knowing to efficiently do so but also lost some of the argument in the process.

The results of this study agree with those of Avraamidou and Osborne (2009) in showing that narrative structure can be effective pedagogy, particularly when the learners are involved in the narrative construction. The teachers were at first the learners/receivers and then became the teachers/narrators, positioning them as participant-narrators. Even though teachers highly valued the primary contextualisation experiences, they generally did not bring them back to the classroom as independent stories. Rather, they used narrative structure to weave together data stories, scientists' stories, and students' stories. As knowledge was shared from person to person, the story structure allowed for credibility and verisimilitude across time and place (Bruner, 1986). Although the authentic data did not always get shared with students, broader extrinsic explanations often did, as shared through co-constructed narrative. As with other TSPs (Shein & Tsai, 2015) teachers were expected to bring their experiences back to the classroom but this may not be the most effective approach. Rather, supporting them to serve as participant-narrators may position them in familiar roles that more effectively bridge the gap between scientists, phenomena, and students.

Limitations and implications

Although the Numbers in Nature project was not designed around the construct of narrative structure, it emerged as a primary theme. The field would be well-served by future research that examines narrative as an intervention. A systematic manipulation of the narrative elements could elucidate how to most effectively use story as a science teaching tool across place and time. This research agenda may also include more explicitly framing the work as a story with an authentic role for students and with a clear mechanism to explore intrinsic as well as extrinsic explanation. The absence of physical setting in the teacher accounts was surprising, particularly because they spoke of it highly when immersed in the dramatic research sites. It may be that teachers simply didn't speak of place that often because it was understood that the interviewers understood it as a key element. Again, this should be specifically investigated.

In this paper, we argued that the teaching and learning of science represents a different activity than the doing of science and that story can play a useful role for helping learners to understand the practices of science as well as natural phenomena. Teachers used data stories to carry extrinsic science explanations to their students rather than the original authentic data. However, story alone does not seem to effectively carry the intrinsic scientific explanations. While there is much potential for using narrative structure to support data literacy and phenomenological understanding, greater intentionality is needed to either incorporate the phenomena of study into the narrative structure or include another mechanism to bring the phenomena into instruction.

Conclusion

Place-based TSPs hold promise for capturing the complexity of authentic science and intentionally transferring that knowledge into specific classrooms. The resulting co-constructed stories become a melting pot of secondary and primary contextualisation. Teachers and students are benefitted by considering how stories are constructed, co-constructed, and re-constructed through transfer, and by intentionally including the full range of narrative elements.

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Appendix

Table A1. Concept codes drawn from existing literature.

Code	Definition
Events	Event tokens: Named events that happened in the past. Past time. Real time action. Chain of events (plot). Perceived sequence of non-random events.
Narrative Appetite	Foreshadowing. Desire to learn more about what happens.
Narrator	Teller standing outside the events, even if present when it occurred originally and relating to another person. Distinguishes narration from expository text.
Agency	Ability to act. Can be a non-living entity that has or is perceived to have agency. Can also be actions that can be seen as parallel to agency- relatable. Things cause or are affected by events. Agency requires intentionality and mechanism.
Intrinsic explanation	Explains some natural phenomenon and is part of the body of scientific knowledge.
Extrinsic explanation	Explains something about science (e.g. process, historical events,), outside the body of scientific knowledge. Unique, non-recurring events.
Narrative explanation	Explains an event as a function of preceding events. Events as causes of other events.
Structure	Reorganizing events and people ('double-time structure'). Story goes somewhere- has or anticipates a conclusion. Often starts with imbalances that end in resolution or failure.
Purpose	Stated purpose or meaning of the story.
Receiver	References to who has or who will be the consumer of the story. Audience must interpret.
Primary contextualisation	Content connections to 'my' experience. Learning in context.
Secondary contextualisation	Content connections to others' experiences. Learning with context.

Codes derived from (Giamellaro, 2017; Avraamidou & Osborne, 2009; Norris et al., 2005)