Cultural Studies of Science Education (2021) 16:47–69
https://doi.org/10.1007/s11422-020-09988-2

ORIGINAL PAPER

"Why would Benjamin Franklin want to know if lightning was electricity?" elementary teachers and students making sense of the nature of science during interactive read-alouds

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Received: 16 May 2019 / Accepted: 19 June 2020 / Published online: 25 January 2021

Abstract
The present study examines the pedagogical use of reading aloud of science trade books as an effective tool for teaching nature of science (NOS) to elementary students. To this end, we explore elementary teachers' and students' dialogic negotiation of NOS during interactive science read-alouds, as well as potential interactions between their sense-making patterns, NOS views, and trade-book representations of NOS. It was found that, when a book had explicit NOS aspects in it, a teacher with more informed NOS views was able to facilitate a more extended, open-ended, and inclusive discussion about NOS. Conversely, when the trade book had very explicit connections, a teacher with naïve NOS views was able to only superficially address these NOS aspects without going beyond or elaborating on the information available in the book. Furthermore, the latter discussion was characteristically close-ended, exclusive of students, and limited in sense-making. These findings underscore the need for further investigation of how particular NOS aspects are narrativized in science trade-books, and how elementary teachers can effectively guide students while facilitating explicit negotiation of particular types of trade book representations of NOS during interactive science read-alouds. It is argued that improving elementary science instruction requires a more sophisticated, theory-based understanding of how NOS instruction is mediated by stories and storytelling.

Keywords Science read-alouds · Elementary science · Teacher-led discussions · Dialogic sense-making

Lead Editor: S. Martin.

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One major goal of science education reform is to produce scientifically literate citizens (American Association for the Advancement of the Sciences [AAAS] 2009). One of the vital components of this goal is the understanding of the nature of science (NOS) (National Research Council [NRC] 2012). NOS can be defined as, "the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, Abd-El-Khalick, Bell and Schwartz 2002, p. 498). To achieve this goal, it is important that students learn about the NOS in school science.

Despite consensus about the importance of NOS learning, the age and grade level in which to start the teaching of NOS has not been entirely agreed upon. This issue motivated a few studies aimed at determining whether NOS understanding is indeed contingent upon age and maturity (i.e., developmental readiness), and clarifying the extent to which elementary students can indeed understand NOS aspects (Akerson and Hanuscin 2007). Valerie Akerson, Ingrid Weiland, Khemmawadee Pongsanon, and Vanashri Nargund (2010b) report that children as young as 5 years old are capable of conceptualizing NOS ideas. This study shows that, with appropriate pedagogy, even the youngest schoolchildren can begin grasping the nature of the scientific endeavor.

A pedagogy endorsed by many as being developmentally appropriate and effective for elementary science teaching is the interactive aloud reading of children's books (Trundle, and Saçkes 2015, p. 219). Reading aloud of informational science books has been shown to help children develop more advanced conceptual understanding and enhanced vocabulary knowledge (Ford 2006). One of the major benefits of integrating such literacy practice into the science curriculum is its sense-making affordances. The important role that science read-alouds play in youngsters' socialization into the specialized products of science (concepts) through meaning-making is well document and widely recognized. Yet, despite the nearly ubiquitous presence of reading aloud in elementary classrooms, its pedagogical potential as an effective tool for socializing youngsters into the specialized epistemic practices of scientists (i.e., make sense of complex and abstract science processes/aspects) remains to be analytically scrutinized by researchers.

Others have endorsed more general instructional approaches rather than specific pedagogies or practices. For instance, some have advocated *highly contextualized explicit/reflective NOS instruction* (Clough 2006) as being the most effective. In this instructional approach, defining features of the scientific enterprise is explicitly and reflectively articulated by teachers and students in the context of an authentic science activity (e.g., a hands-on experiment or a factual science narrative). Under the teachers' guidance, epistemic and social features of science are derived by students from concrete action (content-specific situations like classroom activities or narrative accounts of a scientist's investigative efforts) as opposed to being deduced in an analogical vacuum (content-free representations that capture NOS metaphorically, e.g., the optical illusion in the duck-rabbit drawing).

However, teachers' views and curricular accounts of NOS can vary considerably. Not all elementary teachers hold informed understandings of science (Akerson, Abd-El-Khalick, and Lederman 2000), as not all science instructional materials share the same degree of explicitness and sophistication in their accounts of science. As a result, it stands to reason that several instructional situations are possible. For instance, for a teacher with uninformed NOS views and an unsophisticated/implicit curriculum, effectively teaching NOS is likely a daunting task. The same teacher might be more effective if his/her curriculum provides an explicit and sophisticated account of science (such a curriculum could reasonably compensate for the teachers' personal views to a certain extent). On the other hand, a teacher with informed NOS views and an unsophisticated/implicit curriculum are also likely to be able to manage the challenge of teaching NOS effectively since his/her personal views can help compensate for the less than ideal curriculum. Lastly, the same teacher with a highly explicit and sophisticated curriculum (the ideal situation) is most likely to flourish as an effective NOS instructor. These various possibilities highlight the importance of going beyond hypotheticals and better understand, through systematic analytical scrutiny, the interplay between teachers' NOS views and curricular NOS accounts, as well as the possible interactions with students' emergent NOS views. This is what we set out to accomplish in this study. The research question that guides this study is the following: *How do elementary teachers and students with known NOS views make sense of trade book accounts of NOS during science read-alouds*?

NOS aspects and teaching

Despite general consensus within the academic world with respect to the inclusion of NOS in K-12 science curricula, an agreement is yet to be achieved over an exact definition for NOS, particularly with regard to both the philosophy and history of science (Mesci and Schwartz 2017). Aligned with recent work in this area, we operationalize NOS in terms of aspects (major epistemic features/attributes) that combined capture the essence of what science is as a specialized field and body of knowledge. More specifically, to us, science is tentative, empirical, theory-driven, partly the product of human inference, imagination and creativity, and socially and culturally embedded and therefore not completely objective. Other important NOS aspects include a recognition of the scientific method as a myth, the ability to differentiate between observation and inference, and the ability to distinguish theories from laws (Lederman, Abd-El-Khalick, Bell, and Schwartz 2002).

The best method for teaching NOS to students of varying grade levels and age groups is a topic of considerable debate and research. Teaching strategies commonly used to improve students' NOS views include the provision of historical examples of NOS (McComas 2008), historical narratives about science (Metz, Klassen, McMillan, Clough, and Olson 2007), decontextualized activities that draw students attention to particular NOS aspects by means of metaphorical accounts of science devoid of actual content ("black box" activities, pictorial gestalt switches, etc.). Conducted mostly in higher grade levels and age groups, this body of research highlights that effectively teaching NOS involves careful use of language (laws, theories, etc.), explicit discussion (participation in inquiry does NOT suffice), and contextualization (reflection in the context of actual science content). Very few studies have examined NOS at the early childhood level (Akerson, Buzzelli, and Donnelly 2010a).

Research also shows that NOS misconceptions are widespread and can affect students' attitudes and learning (Akerson and Abd-El-Khalick 2005). It is known that by the time students reach high school, many of them possess misconceptions about the NOS (Moss, Abrams, and Robb 2001). Science is typically seen as completely objective (bias-free), devoid of creativity, following a fixed sequence of steps, producing absolute truths, etc. Such misconceptions about the nature of science are the result of exposure to traditional science textbooks, verification laboratories, lectures, and the media—all of which portray the scientific endeavor as simply an objective pursuit of absolute truths (facts) (Ford 2006).

In addition to holding naïve and uninformed views, many elementary teachers do not favor teaching science and in general are not as comfortable teaching science as they are teaching other subjects (Abramzon, Saccoman, and Hoeling 2017). Furthermore, several studies have shown that holding informed NOS views does not suffice to ensure pedagogical skill or ability to improve students' NOS views. Further research is required to help us better understand how teachers' NOS views and curriculum enactment interconnect in practice.

Trade-book representations of NOS

One teaching method of particular relevance to elementary school science is the reading of trade books—nonfictional children's science books written as informational texts that are accessible to youth. As a practice particularly popular at the elementary school level, reading trade books has been shown to effectively increase elementary students' motivation, understanding of more complex scientific concepts and achievement in science (Kletzien and Dreher 2004). Because of this potential to enhance science instruction, elementary teachers commonly incorporate trade-book reading into their regular classroom practices (Brassell 2006). Only more recently have researchers begun to recognize that trade books also constitute an important source of representations of NOS (not just concepts) to which young students can be strategically exposed in order to help them better understand elusive science processes and develop an improved grasp the complex nature of the scientific endeavor.

Few research articles in science education have examined trade-book representations of NOS (i.e., how science is presented and its epistemic nature represented in trade books). Brunner (2016) completed a study that provided teachers with different levels of intervention to help them develop more informed views of the NOS. Educative guides were made for teachers to use along with their read-aloud books in hopes that the NOS would be more explicitly addressed. However, the guides were not used to their potential and it was found that the teachers needed more professional development on how to use NOS guides. Even so, there was a movement toward more informed understanding of the NOS by teachers with supports in place. This study helps to highlight the complex relationship between teachers' views and practices of the NOS.

Danielle Ford's (2006) examination of forty-four trade books reveals heroic accounts of scientists and an apparent disconnect between science processes and scientific knowledge. The books do not clearly show how data collection is connected to scientific theories, scientific reasoning, or a scientific community. In another study, Cory Buxton and Patricia Austin (2003) report that children's literature tends to portray science as a passive collection of stagnant facts rather than an active process of inquiry conducted by real people. Additionally, Fouad Abd-El-Khalick (2002) examine NOS representations in middle-school science trade books and reported that the books are mostly devoid of explicit references to NOS ideas. For the most part, the nature of science is either neglected or implicitly conveyed in these scientific narratives.

Existing studies that have examined the NOS representations in trade books underscore the critical need for careful consideration and critical assessment on the part of elementary educators. Far from ideal, portrayals of science in commercially available trade books often provide biased, simplistic, disjointed, and distorted accounts of the scientific endeavor. Not only can these problematic NOS representations foster misconceptions, but they can also implicitly convey unintended messages that may inadvertently impact students' NOS views. This trend suggests that the well-documented problem of "questionable content" in science trade books (Schussler 2008) is not limited to the products of science (factual misinformation); it also extends to the processes of science and the scientific endeavor itself.

Uncritical reading of this literature runs the risk of leaving many young students underinformed or misinformed about NOS.

Science read-alouds

In addition to selecting "good" science trade books with explicit and accurate representations of NOS, researchers strongly encourage elementary teachers to use them for their read-alouds. A read-aloud is a pedagogical practice in which a teacher selects a book and then orally delivers it to her students through whole-class reading aloud (as opposed to having students read it individually and silently).

Studies in the field of literacy education highlight that, when effectively performed, science read-alouds can create a sense of wonder and interest and help engage children in science. Trying to capitalize on the "pleasures of reading," elementary teachers often turn to trade books because they are a fun and engaging way to introduce students to new science content (Bircher 2009). For these educators, well-written science trade books with engaging visual features like large, colorful, and bright imagery serve as the motivating catalyst for learning science (Bybee 2006). The present study seeks to add to this literature by examining how interactive read-aloud of trade-books that include representations of NOS interconnect with elementary teachers and students' NOS views.

Theoretical framework

Our theoretical perspective is centered on three main constructs, namely NOS views, curriculum representations, and sense-making. As used in this paper, *NOS views* refer to a set of epistemological beliefs that collectively define ones' ways of understanding the nature and production of knowledge in science. Like other epistemological worldviews (Schraw, Olafson, and VanderVeldt 2012), NOS views develop and are organized through experience, can be changed through learning and reflective thinking and are indicated by verbal belief statements (one's verbal responses to oral and visual stimuli in the immediate classroom environment). Further, in classroom settings, development, and change in ones' NOS views are mediated by discourse (dialogic sense-making), over time leading to increasingly sophisticated levels of cognition.

Our theoretical stance does not simply assume a direct causality between mental constructs (elementary teachers' and students' NOS views) and discourse (what they say). Such an assumption would be problematic in the sense that it would presume the existence of a deterministic relationship between cognition and language. As recent research has shown, spoken language and human thought have a mutually influential relationship characterized by a certain degree of bi-directionality (Gentner, Imai, and Boroditsky 2002). Not only are mental constructs externalized through language but the language is also internalized as concepts, gradually and overtime. Likewise, we conceive of interactive read-aloud of trade-book representations of NOS as entailing simultaneous externalization and internalization. NOS views are expressed outwards through dialogic verbalizations (oral contributions to an ongoing discussion) at the same time that oral messages about NOS are internalized by participants as NOS views.

A diagrammatic representation of this proposed theoretical framework is shown in Fig. 1. As depicted, there are three main components in the NOS read-aloud practice, the

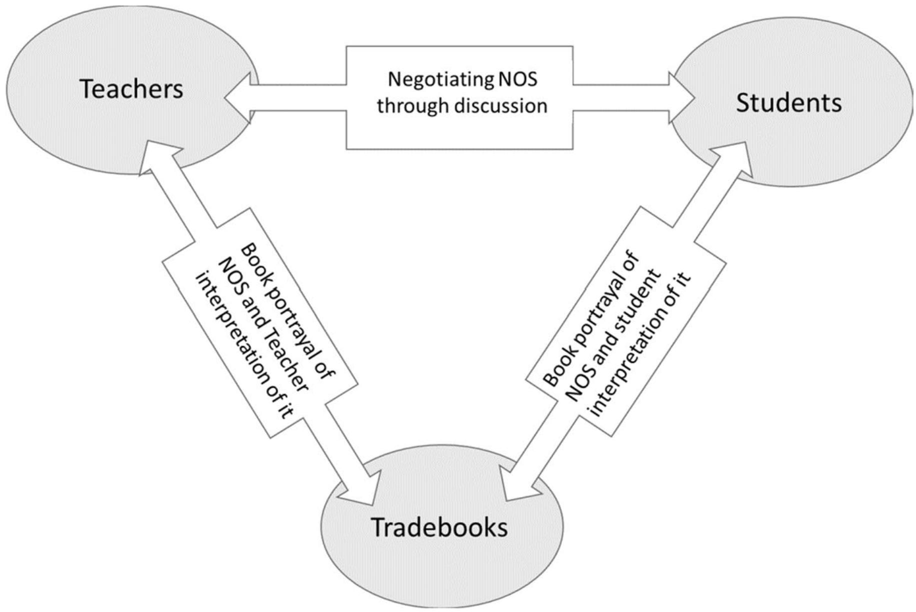


Fig. 1 Read-aloud of trade book representations of NOS

teacher, the students, and the trade book. Teachers and students enter the read-aloud with preexisting views of NOS. Their specific ways of viewing science are revealed by what they say to each other as they attempt to make sense of how the trade book under consideration portrays science and represents the scientific endeavor (i.e., interpret the trade book's NOS message). The book itself is characterized by specific NOS views, those of the book author or curriculum developer. Evidence of the latter can be found in the specific types of textual and pictorial representations used by the author to convey either explicitly or implicitly what science is, as well as noticeable absences. While the teacher is reading the book aloud, the students are hearing the words and seeing the pictures in the book, and creating their own interpretations and understandings of the material. Such exposure to the book's contents and pictures may have some impact on students' understanding of the NOS (as well as the teacher's).

Rather than passive receivers of a NOS message (accepted truths about the nature of science), teacher and students are active co-constructors of meanings. Oral delivery of the text is interspersed with dialogic exchanges wherein the teachers and students share ideas, discuss the significance, provide examples and make intertextual links. As active sense-makers, teachers, and students can also elaborate upon, amplify, and even compensate for gaps or shortcomings in the books' NOS message.

A NOS read-aloud contains not only explicit but implicit messages. An example of this may be a trade book that contains pictures of only white males doing science, giving the implicit message that science is only for white males or during classroom discourse with the teacher, a student understands that science must be done in a stepwise fashion. As recent studies show, implicit messages about NOS can be communicated by teachers' and students' language (word choices, manners of speaking, etc.). Oliveira et al. (2012) describe how elementary teachers and students use hedges (*maybe*, *might*) and boosters (*absolutely*) to express both naïve and developed views of the NOS (science as a tentative or absolute endeavor). Likewise, Oliveira (2011) describes how lack of personal pronoun usage during classroom discussion conveys hidden messages about social and personal tenants of science (science as an impersonal endeavor), inadvertently resulting in NOS miscommunication. What is omitted or left implicit during the enactment of a curriculum, *the absent curriculum* (Wilkinson 2014), can also have significant effects on the learning outcomes of pupils. Thus, our decision to include implicit as well as explicit NOS communication during science read-alouds.

NOS read-alouds under the lens

A multisite naturalistic case study method was used in this study because of its ability to give “intensive descriptions and analyses of a single unit or bounded system such as an individual, program or groups” (Merriam 1998, p. 19). The three main constructs, NOS views, curriculum representations, and sense-making, can be better analyzed using qualitative analysis because of their descriptive nature and to answer the research question. The cases are from different sites so that the teachers, the book choices, and the school culture were all independent from each other. Each case is bound at the classroom level. This study consisted of two case studies in hopes of attaining an improved theory-based understanding of emergent interconnections between teachers’ and students’ NOS views, trade-book representations of science, and sense-making during interactive enactment of a specific type of curricular activity prevalent in elementary science, namely reading aloud. Sharan Merriam (1998) emphasizes that case studies are “particularistic,” meaning that the case study focuses on a “particular situation.” The present study is particularistic because it is focused on two different elementary teachers conducting science read-alouds in upstate New York, a phenomenon in a particular situation.

Participants

To recruit participants, a call was posted on a listserv for elementary teachers in New York State inviting third- and fourth-grade teachers who regularly read science trade books aloud to their students to participate in this study. These two grades were selected because the higher likelihood of there being read-alouds in comparison with upper-grade levels (Fisher, Flood, Lapp, and Frey 2004) and also because the students in these grades are more able to articulate their thoughts, leading to a more descriptive discussion compared to younger grades.

The call for participants was a series of questions that asked for basic demographic information, frequency of science read-alouds, and teacher experience. Teachers were also asked whether they incorporated any activities or discussions during or immediately following a read-aloud. Respondents were emailed the Views of Nature of Science (VNOS) survey (Lederman et al. 2002) to complete. This VNOS survey was used to assess elementary teachers’ views of the NOS.

From the initial pool of prospective participants, we chose to collect data from six different classroom teachers. All six of the teachers participated, and data were analyzed from all six of the teachers. Two of the teachers were selected to present in this study as they were the two “telling” cases while the other four cases exhibited fewer discussions overall. Both teachers selected—Matthew and Vanessa—performed science read-alouds most frequently and whose VNOS scores suggested varied NOS views, ranging from naïve to sophisticated. These two teachers constitute “telling” cases in the sense that “the particular circumstances surrounding [each] case serve to make previously obscure theoretical relationships suddenly apparent” (Mitchell 1984, p. 239). Students from the two selected teachers were also participants and completed the VNOS-D, a version of the VNOS developed for kindergarten through fourth-grade students (Lederman 2007).

Data collection

Our main sources of data collection were the initial teacher survey of science read-aloud practices that were collected through email, teacher and student VNOS (pre-only) that was conducted and collected in person, three visits to each classroom to conduct classroom observations (video-recorded read-aloud sessions), trade books selected for the read-aloud by each teacher, two in-person teacher interviews (post-only), and student-written comments on the read-aloud (post-only) that were collected in person. Our decision not to use the VNOS questionnaires to collect post-data was informed by previous research studies showing that effectively changing students’ NOS views requires extended interventions. As such, it seemed too ambitious and a bit unrealistic to expect students’ NOS views to change considerably after a single read-aloud session (one class period). Nonetheless, collecting data from all of these resources helped give a holistic view of existing read-aloud practices, how teachers’ read-aloud book selections and performances were conceptualized, prepared and implemented, how students understood the NOS, whether the teachers felt their read-alouds were successful, and teachers’ hindsight perspectives.

Both participating teachers were video-recorded while facilitating a science read-aloud session on a date and topic of their choice. As a result, the researcher was able to gain direct access and to witness firsthand classroom read-aloud practices prevalent in each classroom. In keeping with the naturalistic nature of the study, teachers were instructed to make their own trade book selections and not to make any changes to their regular read-aloud practice, a list of the full trade books reviewed are listed at the end of the references. Video-recording allowed the researchers to capture the dynamic discourse that took place during each read-aloud which, combined with notes taken by the researchers, provided multiple opportunities to review and systematically examine the read-aloud performance of each teacher and their students.

Following the video-recording of each read-aloud, teachers were asked about various aspects of the observed read-aloud session, from planning to perceived impact. Examples of prompts include “What did you intend for students to learn during this read-aloud?” and “Do you think this read-aloud gave you an opportunity to teach about science?” Informed by Steinar Kvale and Svend Brinkmann (2009), the interviews were semi-structured in that protocols were flexibly used to guide discussion with the participants and discuss their views of science books and their selection processes. The interviews included questions pertaining to their read-aloud preparation and performance, being audio-recorded and then transcribed.

Data analysis

Three main steps were taken to analyze the multiple data sets collected as part of this study. In the first step, to determine the relative level of sophistication of our participants’ views of the nature of science, we used the scoring process that is established with the use of the VNOS. As part of this process, teachers and students’ are categorized as having naïve, mixed, or informed views. Naïve views of the NOS are evidenced by respondents indicating the scientific method is an objective process, in other words, it is not part of the product of human inference. Naïve views also show up as describing that theories will "become" laws after accumulating evidence and that science is not impacted by culture or individual beliefs. Informed views of the NOS are evidenced by responses indicating science is not completely objective and has creative aspects to it, science is tentative, and science is socially and culturally embedded. And, mixed views refer to intermediate levels of sophistication, wherein participants hold some informed views of the NOS, but also some naïve views of the NOS.

In the second step, the contents of the trade books were investigated based on data analysis techniques developed by Danielle Ford (2006) and Leah Bricker (2005) because they are scholars in the field of science education trade book analysis. As with those studies, the trade books selected and discussed by our participants were read in their entirety for both implicit and explicit messages about the NOS. More specifically, we examined the extent to which each NOS aspect was addressed in the trade books (how a specific aspect of science was represented in the chosen curriculum).

In our third analytical step, audio and video recordings were transcribed and their contents were used data for qualitative analysis. Expansive records of the read-aloud data were examined to identify the main types of discourse interactions that occurred between the teacher and students to negotiate meaning concerning the NOS (key interactions in the read-alouds that highlighted the NOS). These interactions included questions, comments, suggestions, and any other verbal exchange between teachers and students. This approach to data analysis focused on salient features of the read-aloud, including discourse structures such as dialogically oriented read-alouds or questioning strategies that teachers used, such as questioning the author, text talk, and any other discourse specifically related to the NOS.

Descriptive in nature, the latter analytical step entailed within-case as well as cross-case analyses, emergent coding, and constant comparison. A grounded theory approach was taken wherein analytical categories and subcategories were allowed to flexibly emerge from recurrent examinations of interviews and video-recorded observations. Memo writing was also used, helping to identify connections between different emergent categories (Charmaz 2006). Codes were created from initial inspection of the collected data and adapted as analysis proceeded. Examples of the types of codes include the following:

- Hedges/Boosters (H/B code): Representing tentativeness, example words are sometimes, kind of, I think so.
- Pronouns (Pr code): Representing the human endeavor, example words are He, She, You, I, Me, They, We, Your.

Open Question (a question asking for interpretation) or Display Question (a question to which the asker already knows the answer) (OQ or DQ code): Representing that science encourages thinking and interpretation in the development of knowledge, example words are "What do you think…" (OQ) or "What is…" (DQ). Having several data sources such as interview transcriptions, observations, collected artifacts, and weekly memos helped to triangulate the data and substantiate findings (Patton 2002). An example of a memo is

> Go back and look at the VNOS for Matthew and identify the NOS aspects seen in the teaching videos. Further clarify what kinds of questions he is asking students,

> what are the expected answers? Go back and underline the pronouns in the transcriptions. Is there any indication why he chose this book? It's available to him, but any other reasons as well?

In addition to these methods, the researcher discussed the study with colleagues in "peer debriefing" (Lincoln and Guba 1985, p. 243). This type of validity check allowed the researcher to develop interview questions and create and adjust categories when necessary. Our findings are described next.

Matthew's read-aloud

Matthew was a fourth-grade teacher in a rural elementary school. Matthew regularly read trade books to his students either to introduce a science topic or to reinforce an idea or vocabulary. He stated that some read-alouds were strict to "enhance the lesson and knowledge base" in science and some were for both English language arts (ELA) and science. Some examples of the codes from Matthew are found in Table 1.

NOS views

Overall, Matthew had moderately informed views of the NOS concepts. He held an informed view of the use of creativity and imagination in science. His answer to Question 8 on VNOS suggested an informed view of creativity in science: "Creativity and imagination are important to all stages of scientific discovery." Matthew acknowledged that creativity exists in all stages of science but simultaneously expressed the belief that the "facts" come out to be true or proven at the end. The understanding that scientists are individuals with independent thinking and creative thoughts and that the same results will always surface in scientific experimentation or analysis is a trend seen throughout the data set.

In contrast, Matthew's students scored either naïve or mixed on VNOS. Many described science as being different from other subjects because it had laboratories, experiments, and it involved math. Several students made comments about science being fun. A few students remarked that scientists do use their imaginations before doing their work, and two students responded in the affirmative concerning scientists using their imaginations because there is always more than one answer. However, many students associated imagining to not be realistic, considering it fake and having no place in science, where only "facts" should exist, as shown in one example, "Because they need to focus on realistic stuff in their work."

Trade book

Matthew read-aloud *Simply Science Electricity* (Stille 2001), shown in Fig. 2, a book very factual in nature but that also included some history on electricity. One section indicated:

> Benjamin Franklin was a famous American. He lived in the 1700's. People did not know much about electricity then. Benjamin Franklin watched lightning in the sky. He thought it looked like a giant spark. He wondered if lightning was electricity. (p. 9)

This quote illustrated the inquisitive and curious nature of science by showing how a scientist used curiosity to investigate scientific concepts. The description of Franklin

Table 1 Examples of codes from Matthew's case

Time stamp in video	Evidence	Code
2:17	(Matthew)—What kind of electricity do you get when dragging across the floor? (looking for static electricity)	DQ
2:35	(Matthew)—How many of you have gone in a plane to fly…did you notice outside of the window…	Pr
2:48	(Matthew)—Sometimes there are ice particles out there…	H/B
3:18	(Matthew)—Our classroom, uses a ton of electricity	Pr
3:20	(Matthew)—What are some examples of electricity in our room?	OQ
4:05	(Matthew)—Our pets need electricity (and then he starts to point out the animals in the room and how they need electricity)	Pr
5:22	(Matthew)—Does anyone know what the opposite of a conductor is?	DQ
5:54	(Matthew)—You guys know when you grab a power cord, it's not the …the rubber protects you from getting electrocuted	Pr

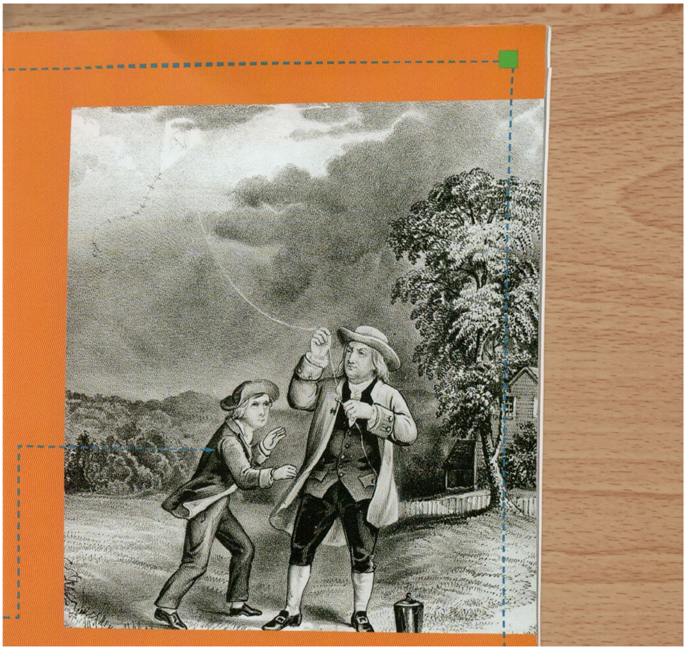


Fig. 2 Trade book on electricity in Matthew's Case

discovering electricity helped show that the scientific method is not a neat step-by-step process. It may be messy, unpredictable, and dangerous, and investigation can be merely a result of human curiosity. The book also showed how electricity is routed to people's homes, becoming a part of their culture. At the same time, it showed the steadfast nature of science when it showed Edison's invention of the light bulb years ago and its continued use to this day.

Sense-making

When Matthew read about Benjamin Franklin, students asked how Franklin knew to try this experiment, leading to the following exchange:

Student: Why would he [Benjamin Franklin] want to know why if lightning was electricity?
Matthew: Because he was a thinker, he was someone who always questioned the world around him?
Student: Why would he do that?
Matthew: How else would he find out lightning was electricity? How would you find out lightning was electricity, if you had to find the experiment. If I said to you, how do you know, how can you prove lightning is electricity?
Student: Well I would watch the lightning if it hit metal and it did [inaudible]
Matthew: So instead of sitting and watching it hit the metal on the roofs he made it, he hit his key by taking that kite and sticking it out there

Student: I'd take a metal rod and put it in the ground and take a string thingy and put it through there. So if the metal got hit it would travel through the thingy and something read it

Matthew: You're thinking that would be a great experiment, so you're saying setting up a tower right? And a metal pole with a graph or chart and tells you when something happens

This discussion illustrates how human creativity and imagination are intertwined with scientific thinking. Various methods of conducting an investigation are put forward, even though the term creativity is never explicitly mentioned. Both in the trade book and the discussion, creativity is implied rather than explicitly named. Nonetheless, Matthew's informed score on both creativity and the myth of the scientific method apparently enabled him to engage his students in an informed discussion about how science is done. Matthew's own NOS views and understandings helped further discussion between himself and his students on the different aspects of science.

Matthew's discussion during the read-alouds included many personal pronouns:

- How many of *you* have gone in a plane to fly…
- Did *you* notice outside of the window…
- *Our* classroom, uses a ton of electricity
- *You* guys know when you grab a power cord, it's not the…the rubber protects you from getting electrocuted
- It's kinda like what *we* talked about a second ago, about water flowing…it's kind of like *you* taking a piece of wood and blocking…
- *We're* going to a house that runs on solar panels and a windmill, and *we* can ask how things works in their house?
- How does *ours* work, how does *our* battery work? Do *you* guys remember…

By doing this allowed Matthew to include his students in the learning process. Many of these discussions that Matthew started incited students to raise their hands and share their own experience with electricity, permitting them to feel included and have ownership over their learning. This may have also helped to give the idea that science is not authoritarian and oppressive but instead open to all citizens. This helps connect to the idea that science is a public affair, including not only specialists but 'regular' citizens as well (AAAS 2009). It also is connected to the idea that science is a human endeavor, that includes all different teams of people as well as individuals (NRC 2012) and that it is a highly social activity.

Matthew's books had very few hedges in them and instead portrayed everything as fact. Matthew may have compensated for this by using many hedges while talking to his students. While this was deliberate or not, helping teachers see how the discourse used in their class is closely connected to the NOS is essential in improving students' NOS understandings.

Matthew addressed six NOS tenets that include creativity and imagination, tentativeness, human inference, social and cultural embeddedness, empirical nature, and theory-driven. Using the coding scheme and contextual discourse of the discussions, it was found that Matthew communicated tentativeness, social and cultural embeddedness, and the empirical nature of science greater *than ten* times in his read-alouds (examples of the codes are in Table 1). Moreover, the other NOS tenets were communicated *between* *five and ten times*. Other memos that were written in Matthew's case included statements such as, "Watch Matthew's video again, did he invite students into the discussion? How so?" and "Underline the hedges in Matthew's videos."

This case suggests that, even when students have naïve views on certain topics, it is possible that the teacher may be able to spark more informed discussions because of his or her own knowledge, especially when the read-aloud book highlights those topics. Benjamin Franklin's experiment described in the book gave Matthew the opportunity to discuss how science is conducted, using imagination, and not adhering to a specific plan. The book acted as a guide, leading the teacher through the science topic, and the nature of the book may have influenced how the teacher was able to stop and ask students questions about the scientific endeavor.

Vanessa's read-aloud

Vanessa was a third-grade teacher who facilitated read-alouds at the beginning of lessons and sometimes during the middle of a unit so that students could investigate what they learned in the read-aloud. She sought to pose open-ended questions ("Why do you think X?" and "How does this happen?"), and she believed that reading aloud was an effective way of engaging students. Some examples of the codes from Matthew are found in Table 2.

NOS views

Vanessa held NOS views that were less informed than Matthew. When asked what science was, Vanessa replied, "science is the study of the things around us." Vanessa also though that science proved things to be true. When asked whether she thought science was universal, Vanessa replied "I believe it is because so many things around us are definite and can be proven through experiments. However, when Vanessa was asked about sociocultural influences in science she said

> I think different science theories do [have different sociocultural influences], such as evolution some people don't believe in it because its not what their religion says about how we were created…so that has to be considered also when we are talking about science. We can't ignore things like religion" (*Vanessa, 3/1/12*).

She argued that she does think science is universal because of her first statement but then also seemed confused because of her statement about religion and evolution. And, when asked about the difference between theory and law, Vanessa answered, "a law is definite where a theory might not be true."

Table 2 Examples of codes from Vanessa's case

Time stamp in video	Evidence	Code
6:49	What kind of person do you think he [Thomas Edison] is?	Pr
9:57	What was Tom interested in now?	Pr and DQ
14:55	How do you think he felt? [when the machine he built was a flop]	Pr

Vanessa's students held largely naïve NOS views. As seen in the other cases, many students associated imagination with "making up knowledge" or even lying. When asked whether scientists use their imaginations, answers included the following:

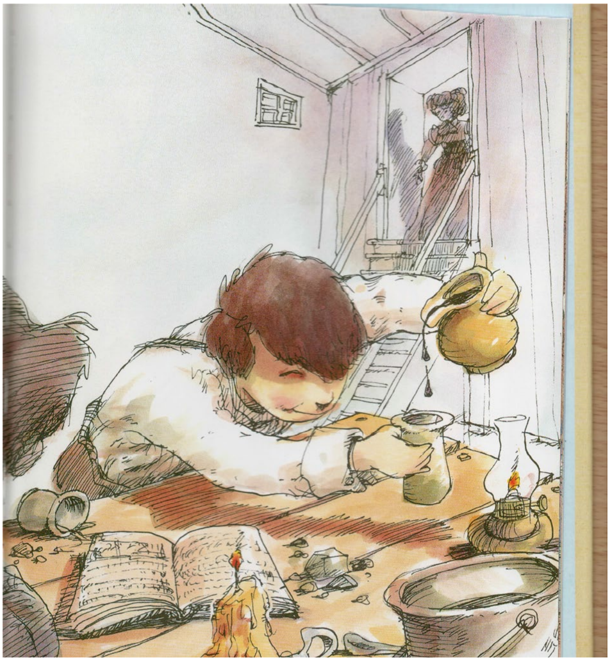
No, because they do research.
No, because they're all about knowing the right thing.
No, because they have to be sure to tell the truth.
No, they have to really think, not imagine.
No, they should think about there work.
No, because they wouldn't say that there was a meteor when they are fibbing.

Students held the idea that using one's imagination is not real, and there is only room for "real" things in science. The understanding of imagination in science, to many students, was that scientists who imagine falsify information, as though they are "cheating."

Trade book

Vanessa read her students the book *A Wizard From the Start: The Incredible Boyhood and Amazing Inventions of Thomas Edison* by Don Brown (2010), shown in Fig. 3. Almost all of the NOS concepts were illustrated in this book, which described a young Thomas Edison growing up curious and inquisitive about the world, experimenting on his own and eventually becoming famous with his inventions. The book emphasized the empirical and investigative nature of science, describing Thomas investigating, first, as a young boy in his family's basement with chemical experiments, and then later spending time developing inventions:

Fig. 3 Trade book on Thomas Edison in Vanessa's Case



> He read history and philosophy books. He read books on mechanics, electricity, and chemistry. They inspired Tom to make a laboratory in the Edison's' cellar. With a pal, he experimented with acids and chemicals. Poor Mrs. Edison worried that they would "blow [their] heads off." (p. 6)

The book showed Thomas to be always curious, wanting to be challenged, tenacious even when projects failed, creative, and hard-working. The famous invention of the light bulb is presented in a way that highlights the tentative nature of science. The creativity, empirical nature, observational nature, and so on are all more apparent in books when the scientist is depicted "doing" the work. Lastly, the book describes how Thomas Edison's experiments changed society (Zarnowski and Turkel 2013).

Sense-making

While reading the book, Vanessa stopped to ask students what they thought Thomas Edison was like as a person. Vanessa discussed the human aspect of science when she read the section about Thomas Edison's failed inventions and his determination still to succeed. She asked students whether they had ever made something that did not turn out the way it was supposed to, and several students could relate. This question also helped to bring students into the field of science, illustrating that, even when imagination and creativity are used, failure can result, but successful scientists keep on working.

There were several instances when Vanessa stopped to discuss parts of the book with her students. In one section titled, "Cleaner Ways to Make Electricity," the book had pictures showing different sources of energy connected to the sociocultural aspect of science. Vanessa briefly stopped after reading the section:

Vanessa:	Because the sun, boys and girls, is the biggest source of energy for the whole entire world…. The sun is very important and creates a lot of energy. How many of you ever saw those things on top of houses they're um, solar panels
Students:	Yeah yeah I have, I saw them on my friend's house
Vanessa:	Okay and what do you think solar panels do?
Student:	It's for the electricity. When it's sunny out, it gives electricity
Vanessa:	I have these little lights outside my house, and you never have to light them up, it gets power during the day and at nighttime they are lit because of the sun's power…. Windmills use energy! They can run a whole town, who's ever been skiing at jiminy peak? At the top of the mountain they have huge windmills and they run the whole mountain!…We're not doing any damage to the sun by having solar lights, we're not doing any damage to the earth by having solar lights. So maybe you want to ask your mom if you can use solar lights around your house. It's a good thing for you to see how they work and you're not saving electricity and you're saving money and it's better for the earth

It is noticeable that, even though Vanessa scored naïve on the sociocultural aspects of the NOS, she stopped and discussed these socio-scientific issues with her students. Part of the reason was that this particular book was explicit with its connection to the NOS; it had both pictures and descriptions of alternative energy. As a result, even with naïve views, Vanessa was able to discuss this NOS issue with the help of a book that made clear connections. It should be noted that the above exchange was not so much a discussion as it was a teacher-led dialog.

Vanessa addressed three NOS tenets in her discussion that include social and cultural embeddedness, creativity and imagination, and the empirical nature of science. Vanessa communicated social and cultural embeddedness and creativity and imagination *less than five times*. Furthermore, the empirical nature of science was communicated *just once* during her read-aloud (examples of codes are found in Table 2.). Even though the book addressed all the NOS tenets, the classroom discussions did not move beyond the three NOS tenets mentioned above. This highlights the complexity between a teacher's understanding of the NOS, the classroom discourse that takes place, and the potential of trade books.

When Vanessa did use pronouns in the Thomas Edison read-aloud, she continuously referred to Thomas Edison as Thomas, Edison, he, him, and his. While pronouns are used here, the use of third-person pronouns situates Thomas Edison as the expert and the students as the outside observers of science. At one point, Vanessa asked the students what they think of Thomas Edison, the students stated "he enjoys to read" and then Vanessa added that he is "educated." This may also contribute to the idea that students are situated as outsiders in science.

As mentioned above, Vanessa held largely naïve views of creativity, methods of investigation, and sociocultural connections to science, but the book showed explicit NOS in both text and pictures. Vanessa mostly responded to students' answers or questions with an affirmative 'yes' or 'right' but does not go on to communicate scientific meaning-making to the students. Vanessa made sense of the NOS portrayed in the trade books at a simpler level. This is not a surprise because Vanessa scored the least developed views of the NOS. However, this shows how a book with explicit pictures and text related to the NOS has good potential in bringing the NOS into read-aloud discussions. The book aided in helping the students think about the connection between science (the light bulb) and the NOS (the experience and struggles of the scientist on his path to inventing the light bulb). This case reveals that trade books with clear and explicit connections to the NOS can effectively help foster informed discussions with students, even when the teacher has naïve views on a NOS aspect.

Discussion

Our findings highlight science read-alouds' potential to serve as powerful curricular spaces for engaging children in informed sense-making about the nature of science. Interactive reading aloud of children's books offered our participating elementary teachers and students unique opportunities to dialogically and reflectively negotiate trade-book representations of NOS. Across both cases, informed sense-making was particularly pervasive when the teacher held more informed views about a given NOS aspect and the trade book explicitly highlighted this same NOS aspect. Matthew's informed views of creativity and the scientific method seemed to enable him to engage his students in an informed discussion about the creative ways that Benjamin Franklin experimented with electricity (explicitly described in his trade book).

When teacher views were less than well-informed, the extent to which the NOS aspect was presented in the trade books had more significant effects on how much the NOS was raised and made sense of during classroom exchanges. This was particularly evident in Vanessa's read-aloud. Her largely naïve views seem to limit her ability to spark informed discussion and provoke in-depth sense-making of NOS. Unlike the other case, Vanessa refrained from elaborating on the information available in the book. Nonetheless, the clear and explicit NOS representations (pictures and texts) in her selected trade book helped ensure that the sociocultural aspect of science was not completely overlooked or left implicit.

The above findings indicate that having informed views influenced the teachers' ability to effectively lead a discussion involving NOS topics. Teachers' ability to facilitate oral sense-making of trade-book representations of NOS was at least in part contingent on the degree of sophistication of their epistemological understandings regarding science. Teachers with more informed NOS views tended to be able to translate them into explicit classroom discussions more skillfully. Such a finding is consistent with previous research showing that effective, explicit instruction about NOS requires, among other things, having more informed NOS views (Akerson and Abd-El-Khalick 2005). Moreover, as emphasized by scholars of reading aloud in the field of literacy education, when trade books are read to children, it is assumed that the teachers will be able to help their students understand the concepts in the book as well as help them figure the out the meanings of pictures and text presented (Schussler 2008). As our findings have shown, the same seems to hold true for NOS concepts and their visual and textual representations in children's science books.

However, teachers' views alone may not be enough to ensure pedagogical ability to create meaningful discussions about the NOS and possibly change students' understandings of the NOS. As described above, having trade books with well-written and explicit connections to NOS can also help teachers have NOS-related discussions in class. The trade books alone were not sufficient to create meaningful and productive discussion about the NOS. In the examined classrooms, doing so required teacher agency in the form of pedagogical ability to elaborate on the trade book and go beyond the information provided in the book. Teachers had to be able to expand on the trade-book representations of NOS based on their prior knowledge and experience.

The above finding is in line with prior research showing that teachers need help taking their NOS views and translating them into explicit classroom discussion (Akerson and Abd-El-Khalick 2003). This is precisely what trade books with highly explicit NOS representations did for our participating teachers. They provided teachers with opportunities to raise and communicate NOS ideas to students even though these may not have been well understood and teachers may not have been comfortable discussing them with students more thoroughly. This finding highlights the value of science trade books as a form of curricular support for elementary teachers when it comes to NOS instruction. Therefore, in addition to being provided with professional development opportunities, it seems critical for elementary teachers to have access to trade books with high-quality NOS representations.

NOS is thought to be an essential part of the K-12 science classroom learning experience, yet, prior to this study, hardly any attention had been given to how elementary teachers and students made sense of NOS during science read-alouds. Some studies had examined how NOS was presented in books and curricular materials for elementary classrooms (Ford 2006), but how teachers enacted this curriculum with students was yet to be subjected to systematic analytical scrutiny. The present study is preliminary work but critical since curriculum enactment as just as important as curriculum development as a source of new insights for science educators who set to teach NOS to children. We encourage other researchers to use this framework and data analysis method to review more science trade books

Creativity in science

A trend seen in both cases was a strong focus on scientists' creativity or imagination. As described above, many students thought that scientists were not creative or imaginative in their research work. Moreover, even though the trade books' narratives implicated/hinted at creative and imaginative performance on the part of scientists, their scientific work was not identified as such; science creativity was enacted by characters but not labeled as such by the authors. This NOS idea also remained largely implicit and unnamed in the discourse that took place during the examined science read-alouds. The findings are consistent with previous research shows that misconceptions about the nature of science abound (Akerson, Abd-El-Khalick, and Lederman 2000). When questioned whether scientists use their creativity and imagination during investigations, students and teachers typically provide responses such as "No, they [scientists] just have to give the facts, not imagine the stuff," "[you] can't pretend things in science, so you can't imagine stuff," and "logic plays a large role in the scientific process" (Akerson and Abd-El-Khalick 2005). Creativity is commonly viewed as an essential feature of artistic work, whereas logic and reason are the defining attributes of scientific inquiry—science is an intellectual endeavor devoid of creativity and imagination. Many elementary students are yet to recognize that scientific knowledge production has a creative dimension. For this reason, explicitly identifying discussing how the concepts of creativity and imagination also apply to scientists' ways of thinking is essential to help clarify students' understandings about this particular NOS aspect.

As emphasized by Alfonso Montuori (2012), "historically, creativity has been consistently mythologized and misunderstood." What exactly it means to be creative can vary considerably depending upon one's field of scholarship, disciplinary affiliation, and philosophical commitments. Vlad-Petre Glăveanu (2010) identifies three distinct paradigms in creativity theory and research. In the more traditional paradigm, creativity is the province of a few unique individuals endowed with the unusual human capacity and intellectual ability (geniuses). This paradigm deals with *historical creativity* (Fischer, Giaccardi, Eden, Sugimoto, and Ye 2005) in the sense that it refers strictly to the highest level of creation, namely game-changing novelties and paradigm-altering innovations that constitute landmarks in the history of a field (e.g., the work of eminent scientists like Einstein and Darwin). In the second paradigm, focus shifts to *ordinary creativity* (Bateson 1999) and *mundane creativity* (Cohen and Ambrose 1999). Rather than dealing with the revolutionary breakthroughs of the "great creators," this is about the creative performance of the "normal person" (common creative acts, creative cognition, creative abilities, creative personalities, etc.). The third and final paradigm is concerned with *social creativity* (Purser and Montuori 2000). Instead of being the result of internal dispositions (i.e., the outward expression of innate abilities and personality traits) of the individual, creativity is conceived as a collective achievement influenced by social factors such as group interaction and collaboration. It emerges in social contexts that are supportive and conducive to the performance of creative acts (i.e., creativity is socially enacted and is located in group space rather than inside the "individual").

In alignment with the first paradigmatic perspective, the trade-book representations of NOS and the discussions facilitated by both elementary teachers emphasized historical creativity. Their primary focus was the revolutionary breakthroughs of "great creators" such as Benjamin Franklin and Thomas Edison. Science creativity and imagination were invariably associated with being a genius (i.e., an outward expression of innate abilities or personality traits of very unusual individuals). Hardly any attention was given to more common creative acts of ordinary or "normal" people (other than historical figures or science celebrities). Such finding points to the need for elementary teachers to read science trade books that also portray *ordinary* and *mundane creativity*. Furthermore, explicitly identifying creative acts and discussing how the concepts of creativity and imagination also apply to scientists' ways of proceeding and thinking may help clarify students' understandings about this particular NOS aspect.

The above finding highlights the need for science educators to better understand how NOS concepts are narrativized in children's science books. In them, NOS is enacted in particular ways through the actions of characters and the unfolding of particular plots. As such, science trade books serve as a s*toried curriculum* (Sandlos 1998) and provide children with literary representations of NOS concepts. Unfortunately, as our findings showed, NOS concepts are often narrativized in problematic ways in trade books, hence providing children with epistemic representations of NOS concepts that are too implicit or limited such as the reported biased focus on historical creativity. As a result, their reading aloud may fall short of telling the "real story" of science as a human endeavor. Avoiding such a complication will require careful consideration of narrativization issues as well as recognition narrative constitutes a fundamental means for making sense of our world (Abbott 2008). Science is no exception. Other research that has also looked at the NOS in trade books during teacher read-alouds emphasizes the need to further explore this area of science education. Brunner's research on the NOS and read-aloud (2016) states.

> The current evidence suggests that repeated use of similar materials across contexts and content will likely deepen teachers' understandings of NOS, increase their level of comfort with these understandings, and, consequently, help them to better and more effectively infuse NOS instruction into their science instruction (at least, when taking the form of reading science trade books).

Brunner's study suggests that with proper support teachers can understand the NOS at a deeper level and then more accurately teach the NOS in their classrooms.

Conclusion

These findings underscore the need for future research to further investigate how particular NOS aspects are narrativized in science trade-books, and how elementary teachers can effectively guide students while facilitating explicit negotiation of particular types of trade book representations of NOS during interactive science read-alouds. Improving elementary science instruction requires an improved, theory-based understanding of how NOS instruction is mediated by stories and storytelling. These findings also contribute to the knowledge base by showing science teacher educators how they can help science teachers better understand classroom interactions, the role of language in classrooms, and how their own understanding of science may impact their students. Attaining such an improved pedagogical understanding, we believe, is critical to ensure that the scientific enterprise is presented with accuracy and explicitness as an unfolding story within the reach of even our youngest students.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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