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Abstract

The purpose of this study is to explore third grade elementary students' Nature of Science (NOS) identities as a result of participating in a unit on electricity. The study took place in the context of a diverse third grade "at risk" (as identified by state regulations) classroom. Videotapes were made of all aspects of the electricity lessons, including pre-lesson class discussions, activities engaged in by students, and follow-up class discussions at the conclusion of each lesson. Findings revealed that third graders began to develop identities of persons who conceptualize NOS. Even though through one unit they did not address all aspects of NOS, they showed great development in their identities for young third grade students.

Introduction

The main goal of science education is scientific literacy for all students to develop scientific knowledge (Abell, & Smith, 1994). Scientific literacy involves understanding not only scientific content, but also understanding the nature of science (NOS) (Abell, & Smith, 1994, p.475). NOS has been defined as "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick, Bell, & Lederman, 1998, p. 418). Understanding NOS is critical because it helps students to understand the development of the scientific knowledge and to develop informed decision-making skills. However, previous research has revealed that students and teachers have not achieved adequate understanding of NOS and so, their views of NOS are not compatible with contemporary understandings of the scientific enterprise (Abd-El-Khalick, & Lederman, 2000; Duschl, 1990; Lederman, 1992). This lack of understanding related to the scientific enterprise can relate to students developing negative views and perceptions toward science and scientists. Finally, the negative views and images of science and scientists held by students seem to affect students' science identities and interest in science (Kelly, 1987; Song & Kim, 1999). Specifically, it is crucial for students to have positive images and views towards science and scientists because these can affect the number of students pursuing advanced science and mathematics courses in high school and those going on to choose scientific careers (Cakmakci, Tosun, Turgut, Orenler, Sengul, & Top, 2011; Finson, 2002; Kelly, 1987; Wong, Firestone, Ronduen, & Bang, 2016). In this sense, negative views towards science and scientists can become a serious barrier to the possibility of having a more racially and ethnically diverse population in science, as well.

Chambers (1983) conducted a study to determine at what age children first develop distinctive views and images towards science and scientists. The findings of the study revealed that stereotypical images begun to appear in the child's consciousness in the second and third year of schooling; by the fourth and fifth year the image has fully emerged (Chambers, 1983, p.260). Therefore, lower elementary grade teachers have an important responsibility to introduce students to more accurate images of science and NOS and help students to start developing NOS identities at the early stages of the schooling. Attempts to improve students' views of NOS are critical to prepare students for the future, as informed citizens. Previously, it has been asked whether young children could actually understand nature of science (NOS) aspects, the research revealed that young children can indeed develop adequate and accepted views of NOS through effective instruction (Akerson, Carter, Pongsanon, & Nargund-Joshi, 2019). Focusing on teaching NOS aspects to students in early grades is a very effective approach since it provides opportunities for students to develop better views of NOS and science content understanding in later grades (Akerson, Buck, Donnelly, Nargund & Weiland, 2011).

Lederman emphasizes that NOS should be an explicit component of science curriculum and students need to be engaged in activities and reflections that offers opportunities for them to develop better understanding related to NOS aspects. Explicit-reflective NOS instruction can be used to teach NOS tenets either through direct exposure to science concepts or through independent activities and discussions. Explicit-reflective NOS instruction is aimed at introducing NOS to students with or without incorporating science content as well as providing students opportunities to obtain feedback and to modify their NOS ideas based on this feedback (Akerson, Abd-El-Khalick, & Lederman, 2000). In the literature it has been documented that young children can demonstrate adequate NOS understandings as a result of explicit-reflective inquiry instruction (Akerson, Buck, Donnelly, Nargund-Joshi, & Weiland, 2011; Akerson & Volrich, 2006; Quigley, Pongsanon, & Akerson, 2011).

Our method for investigating students NOS understandings is grounded in the concept of identity. Prior research has documented that development of elementary teachers' identities as teachers of NOS is critical for their conceptualization as well as instruction of NOS (Akerson, Pongsanon, Nargund, & Weiland, 2014). Could this also be one of the solutions to assist elementary students in the development of their views of NOS? The purpose of this study is to explore third grade elementary students' NOS identities as a result of participating in a unit on electricity. During this study, we observed students' NOS identities through NOS aspects. It is critical for students to understand these NOS aspects to be able to develop an identity as someone who understands and make informed decisions about science. The main research questions are "How do third graders' NOS identities develop as a result of participating in an electricity unit?" How do students' engagements in the electricity unit contribute to their understandings of NOS?

Identity

The concept of identity has increasingly been a focus of research in many disciplines (Bonner, 2010; Hrabowski, 2012). Similarly, many science education researchers are interested in this concept to better comprehend students' understanding in science classrooms (Akerson, Elcan Kaynak, & Avsar Erumit, 2019; Barton, Kang, Tan, O'Neill, Bautista-Guerra, & Brecklin, 2013; Brickhouse & Potter, 2001). According to Barton et al., (2014) "identity is a powerful construct for understanding student learning because identities are constructed through practice" (p. 41). While identity is a valuable and beneficial tool to understand student learning in science, identity studies are complex (Barton, Kang, Tan, O'Neill, Bautista-Guerra, & Brecklin, 2013). This is partially because identity is a multifaceted, dynamic and evolving concept, which is affected by many variables. Holland emphasizes that identities--if they are alive, if they are being lived--are unfinished and in process (p.vii). Due to conceptual and methodological difficulties in this task, it is almost impossible for researchers to observe every aspect of identity work over time and space (Barton, Kang, Tan, O'Neill, Bautista-Guerra, & Brecklin, 2013).

Identities develop in social practice (Holland, 1998, p. vii). For students, schools and classrooms are important social contexts where students' identities to evolve. In this sense, while there are a wide variety of ways that researchers conceptualize identity, we will focus on conceptualizing identity through its connection to individual experiences and environment (Akerson, Weiland, & Elcan, 2015). Even if identity studies are getting attention (Carlone, & Johnson, 2007; Eisenhart & Finkel, 1998; Hughes, 2001; Tan & Calabrese Barton, 2007), the studies that specifically focus on nature of science identity are limited. The current study suggests, therefore, new perspectives on development of NOS ideas. We believe investigating NOS embedded in the notion of identity is critical because it might help students to "…think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (NAE & NRC, 2014, p. 20). With this in mind, in this study, we focus on third grade students' versatile experiences in their classroom to explore their NOS identity development through NOS instruction embedded in a four week electricity unit. Researchers conceptualize identity in a variety of different ways using different lenses and framework. Our framework is constructed on developing identity of nature of science (NOS) which is a multifaceted concept.

Children are able to conceptualize various dimensions of NOS starting from five age, with proper instruction, and as they grow up they show better development of NOS identity (Akerson et al., 2019). Childrens' NOS development generally begins with concrete aspects such as observation and inferences to more abstract aspects as subjectivity (Author et al., 2019). During this process, explicit reflective instruction plays an important role in the development of NOS identity, allowing children to reflect on the science investigation they were doing through drawings, writings and verbal statements. Previous research has shown that the explicit-reflective approach is critically important in assisting children improve their conceptions of NOS in both informal settings with young children (e.g. Akerson et al., 2019) and in a traditional classroom context with older children (e.g. Khishfe & Abd-El-Khalick, 2002; Khishfe, 2012; Khishfe & Lederman, 2007). Considering this fact, we chose to use explicit-reflective NOS instruction, embedded in the third-grade science content, to teach NOS aspects.

Method

This qualitative study investigated third graders' NOS identities during an electricity unit when NOS was taught through an explicit-reflective approach. The data of the study were part of a year long project to improve NOS conceptions in a third grade class in an elementary school in the US. The purpose of the project included the second author exploring how to teach NOS embedded within each science unit, to determine changes in students' NOS understandings as well as exploring students' NOS and science identities. In the one year project, students were engaged in numerous inquiry-based science activities through units including gravity, fossils, rocks, and electricity. At the beginning and the end of the projects participant students were both surveyed and interviewed to determine growth in their understandings of NOS and science content. After each lesson critical conversations took place with students regarding their learning and engagement in the activities. At the end of the project, a large amount of data had been collected from several sources including video-taped class sessions, interviews with students, students' drawings and written reflections. This study is written based upon the data collected from the 4 week electricity unit. We purposely chose this unit taking consideration students' engagement and active participation in the explorations on electricity. In comparison to other science activities, the unit of electricity drew attention of students and seems to contribute to their understandings of science.

To identify development in identity videotapes were made of all aspects of the electricity lessons, including pre-lesson class discussions, activities engaged in by students, and follow-up class discussions at the conclusion of each lesson. Videotapes were also made of discussions surrounding children's literature that were used within the lesson. Copies of student work were collected, including daily recordings regarding electricity and NOS in science notebooks. Additionally, photographs were taken of students' circuits and records of ideas about electricity and NOS.

Intervention

This study took place in the context of a diverse third grade "at risk" (as identified by state regulations) classroom of 24 students during a four -week electricity unit at a United States public school. The second author was the teacher, and was an experienced elementary teacher who was also a university professor of science education, and therefore had experience teaching NOS at the university and elementary levels. The goals for the unit were to teach about electric circuits, conceptualize distinctions between parallel and series circuits, and develop conceptual understanding of electricity as an energy source. Other goals were to embed NOS aspects into the electricity content such that third graders could develop identities as "persons who understand nature of science." The aspects that were targeted are those in the National Science Teachers Association (NSTA, 2000) position statement that (a) scientific knowledge is both reliable and tentative, (b) no single scientific method exists, but there are shared characteristics of scientific approaches to science (e.g. scientific explanations are supported by, and testable against, empirical observations of the natural world), (c) creativity plays a role in the development of scientific knowledge, (d) there is a crucial distinction between observations and inferences, (e) though science strives for objectivity, there is always an element of subjectivity (theory-ladenness) and (f) social and cultural contexts play a role in the development of scientific knowledge.

Activities included making simple circuits with batteries, bulbs, and wires, exploring conductors and insulators, building flashlights, wiring a small model home, among others. Each day students recorded their ideas about electricity content as well as conceptions of NOS aspects in their science notebooks. Class discussions about electricity and NOS were held prior to and following each activity, and the teacher recorded the main ideas of these discussions on chart paper (as well as videotape). Children's literature was used to support electricity content knowledge as well as NOS content knowledge.

In the first lesson, the instructor (second author) held a discussion regarding the place of electricity in human life and asked students what they already knew about electricity. Students both orally and verbally reflected on the question and stated numerous ideas about the sources of electricity and how it works. The instructor created a chart and recorded what students stated. Students also wrote what they already believed they knew about electricity in their own notebooks. In the second lesson, the instructor explained to students that we used electricity in our houses, schools, offices and most other places. She asked them if they had any idea about how electricity arrives to our houses and how it works. Students again reflected on the issue, discussed in the class and recorded their ideas in their notebooks. In the third lesson, the instructor showed students batteries, bulbs, wires and told them it might be possible to make the bulb light using all these materials. She asked students to explore how to make the bulb light using those materials. Students first engaged in discussion with their classmates and shared ideas how they might get bulbs to light using the given materials. In the next lesson, students made several trials for making circuits and drew all their trials on their notebooks. Subsequent lessons had students engaging in exploring parallel and series circuits, as well as various bulbs, exploring switches, building flashlights, and building a house from a box and wiring it with lights, At the conclusion of the unit, students reflected upon what they learned, and responded to the introductory questions again so the instructor could check for change in understandings.

During each lesson the instructor put an emphasis on NOS, such as stating "Are we certain that we know all the ways to light a bulb using a battery and a wire? Would we ever change our minds?" When students responded, "well, we can't be all the way sure, because we haven't tried everything," the teacher responded "That is a good response—scientific knowledge is tentative, that means it can change if you collect new data, or you think about existing data in a different way. Science is reliable, but it is also changeable. So we might change our own ideas about what we explore, as we collect more data." Similarly, she continually emphasized to the students that they were very capable of conceptualizing NOS ideas. One such statement was "Did you know that some people think third graders cannot learn about nature of science? I believe you can. I already see how you have learned so much about it so far—now you can explain the ideas to others! You are going to be able to tell all the adults about the nature of scientific knowledge!" Statements like these contributed to their NOS identity development.

Data Sources

Using multiple methods of data collection in any research approach maximizes the inherent strengths and minimizes the limitations of that approach by providing various sources of evidence (Patton, 2002, Yin 1994). This evidence can take different forms such as interviews, observations notes, and any written, visual and audio materials (Yin, 1994). Considering this fact, we collected data using four instruments: (1) videotapes of class sessions, students' notebooks and any written and drawn material by students throughout the unit, classroom pictures, and reflective notes of the instructor (second author).Collecting four types of data sources allowed us to triangulate our findings with strong evidence and minimize the weaknesses of each data source.

Data Analysis

In line with interpretive data analysis, data were reviewed separately by the first two authors in total to determine emergent categories indicating students' understandings of NOS. We conducted a thematic-analysis with data derived from the videos (Boyatsiz, 2008; Patton, 2002; Saldana, 2009). Videotapes and transcripts of videotapes were reviewed by both researchers and emergent themes were compared. To apply thematic analysis, we used an inductive, iterative approach that allowed us to see recurring patterns and repeated statements throughout the set of data (Saldana, 2009). We first coded initial patterns using descriptive codes that referred to a summary of the basic topic of the data in a word or a short phrase (Saldana, 2009), such as "NOS understanding" "Teacher emphasizing NOS identity". In the second phase, we categorized the codes based on commonalities and differences within and across transcripts. In the last phase, we generated themes by combining codes. Table 1 provides an example of how we created themes:

Table 1. Codes for analysis

Short phrases for codes	Categories	Themes
Energy comes from the light Energy comes from the sky Batteries produce energy	Students relate electricity to energy	Students have background knowledge about the connection between energy and electricity.
Scientists use observations and inferences Scientists create knowledge	Students are developing ideas about NOS	Students are capable of learning NOS aspects
Students are talking about NOS ideas together Students are writing NOS ideas in their notebooks without prompting	Students can use terms appropriately in written and oral discourse	Students are developing NOS identities

After creating themes, any discrepancies, which were few, were resolved by further consultation of the data. Following review of video data, students' work and drawings were also reviewed and analyzed to determine knowledge about electricity as well as NOS.

Results and Discussion

Electricity and Energy are Interconnected

In teaching the electricity unit, when the instructor (second author) asked 3rd graders to describe what they already knew about electricity, almost all students tended to discuss their conceptualizations of electricity through examples from real life rather than providing specific definitions. For example, referring to thunderstorms Tom stated, "[Electricity] is energy that comes from the sky." Supporting Tom, Emily added that "[Electricity] is energy produced by light". Then Greg composed a similar conceptualization with just one slight difference: "electricity is energy that makes heat or light." The main idea raised by these three students was that there is a connection between electricity and energy. These ideas were mentioned by many others. Even though they did not fully explain the details of this connection, based upon their life experiences they were able to see that they were interrelated. In explaining electricity, the students repeatedly referred to energy using similar phrases like " hot streak of light," "belt of energy," "power," " beam of energy," " ray of energy." From these reflections, it could be inferred that students have some previous knowledge about electricity and in light of their background knowledge they made assumptions. The teacher made use of this information by stating to the students "You are all using your background knowledge to describe what you know about electricity. Scientists do this too, so when they are looking at their data, how they interpret it is influenced by what they already know. In a sense, they are making observations of the data, and inferences about what that data means based on what they already know." As has been stated previously, students' conceptualization of NOS begins with concrete concepts to more abstract concepts. The students repeatedly referred to electricity as "powerful energy." It was emerged from the students' reflections that third graders first conceptualized electricity attaching to concrete examples they saw in the everyday life. Related to their real-life experiences, they tended to attribute how electricity works.

Electricity is Created by Something

When the instructor asked students how electricity might work, students first made inferences that electricity was produced by something. Accordingly they stated ideas regarding something creating electricity such as "sometimes the sky creates it," "satellite gets signals to produce electricity," "batteries made it up," "batteries suck energy and it works, then quit working because it gets tired." As students' responses show they had some ideas about how electricity was produced and they related their understandings using concrete examples to their real lives. Even they were not exactly sure about sources of electricity, they made assumptions using their background knowledge and made inferences. Some students made further comment that electricity is something that moves. Kate stated " Electricity goes through an energy lines by places that get it," Heidi provides another assumption that " I think if you turn on a bunch of electricity in powerline the electricity goes," Terry explained "electricity moves through metals." The main idea from students' responses is that they believed electricity includes "flowing," "stored up," and "used." After students shared what they already knew about electricity, the instructor asked students what a scientist would do to learn more about electricity. Jen responded that "they can think what might happen." Joseph stated "[scientists] make guesses," Emily said "predict." Even though students tended to use different labels, they all figured out that scientists make predictions which is an important aspect of developing NOS identity.

Making Electrical Circuit

When the instructor showed students a wire, battery and light bulb, students understood that they need to make predictions for how the materials would need to be connected to light the bulb. Tom made the first prediction that "you will touch the wire to the battery, a bulb will light up." Following his statement students discussed how they made connections among all these materials to make an electrical circuit. Students drew models of electricity circuit.

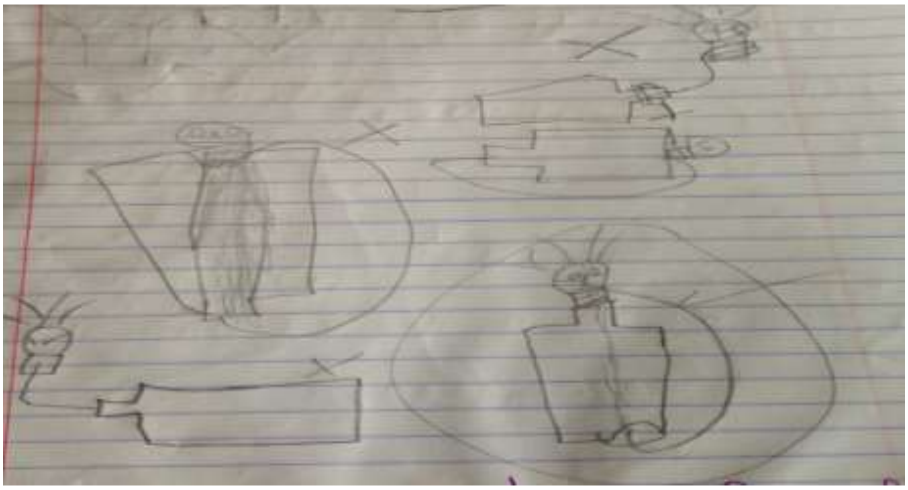

Figure 1. Mary's drawing

As an investigation in the unit each student was given a bulb, wire and battery and asked to figure out configuration for how the bulb might light. During the investigation process, students listed their observations. They tried numerous ways to light the bulb, and finally figured out various ways to light the bulb. In their investigations students followed a creative approach and found multiple ways for lighting up a bulb. Then students drew models of electrical circuits they tried. For instance, from a review of their drawings, Mary had five different models about how a bulb would light (see Figure 1). She put " X" for not working circuits and put " thick" for ones that working. In a similar way, Alex drew his model of an electrical circuit in his journal entry following as (see Figure 2).

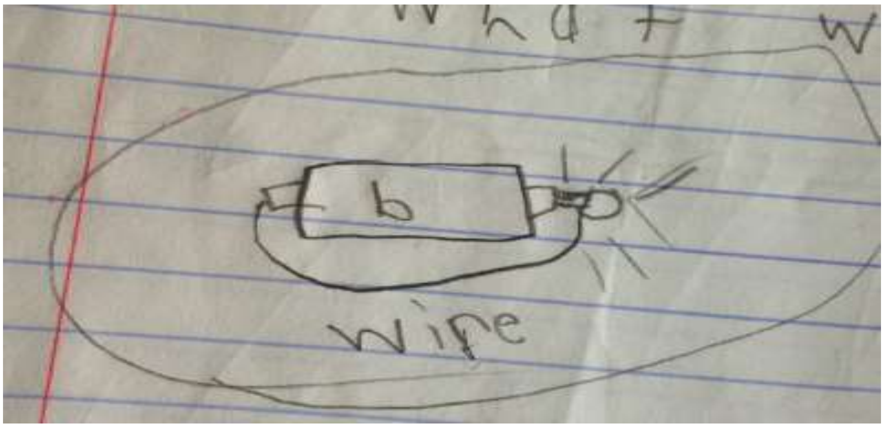

Figure 2. Alex's representation of how electricity works

Similar to that, Tom drew his way of making a circuit (see Figure 3).

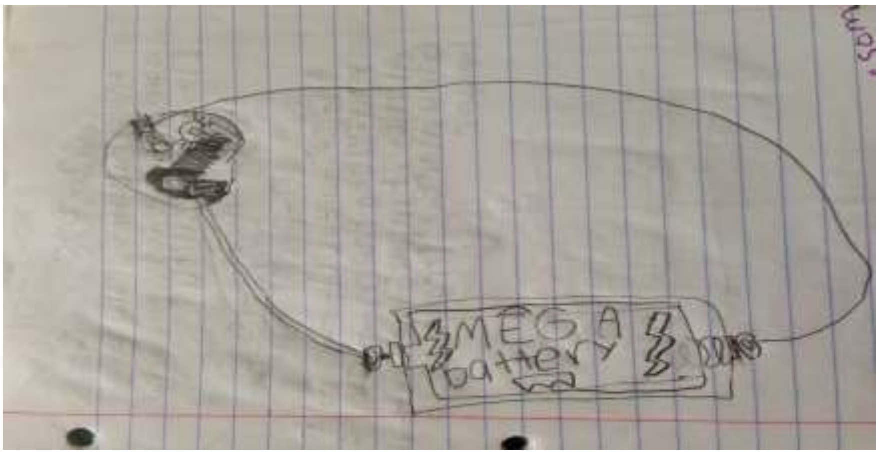

Figure 3. Tom's drawing

Learning to Act as Scientist

After debriefing the students' explorations, the teacher asked students to look at their observation notes, and to share "what can we infer that electricity needs in order to make things work." Students gave meaningful responses, for instance Jack stated, "it has to have metal," Mary said "electricity travels through wires, and lots of paths for electricity" and added that "electricity needs to go in a circuit to work." Students' statements illustrated their understandings of observations and inferences. In the last part of the unit, students compared their previous knowledge about electricity with what they learned through investigations. The third graders' investigations exploring electrical circuits allowed them to act as scientists. As scientist do, students first made predictions regarding how they thought they would correctly design the electrical circuit. They then made observations of what they tried, and listed their observations and at the end they tried whether their designs worked to light the bulbs.

At the end of the activity students had realized that some of their assumptions they made at the beginning of the unit such as "batteries suck energy" or like "electricity is energy that makes heat or light" seemed to be supported. That means students' background knowledge and previous experiences helped them to make reasonable predictions. Through this activity students explicitly learned NOS aspects, including inferring, prediction, observing, scientific imagination and formulating models, which help in their NOS identity development. Though some students were better than their classmates in understanding NOS concepts, they all showed improvements. Using imagination and creativity, students tried multiple ways to figure out what electricity needed to work. All students had some subjective knowledge about electricity and used these ideas in making assumptions. Students acted as scientists and used their background knowledge, creativity and imagination, followed a scientific approach and created empirical data. After their investigations, they made sense that their observations helped them in making inferences.

It is obvious that third graders began to develop identities of persons who conceptualize NOS. Through this single electricity unit they did not address all aspects of NOS, but they showed great development in their NOS identities for targeted conceptions for young third grade students. Along with conceptualizing electricity content, they also conceptualized ideas about NOS, and developed their NOS identities. In teaching the unit about electricity, the instructor used an explicit-reflective approach in the third grade classroom. Through this approach students were allowed to act as scientists who make scientific investigations while explicitly discussing, and reflecting on different aspects of NOS within the context of science. To encourage students' reflections, the following poster showing aspects of NOS hung on the classroom wall. The teacher referred to this poster to help students conceptualize NOS and reflect on elements prior to and following electricity activities. Students also referred to the poster when they were sharing their ideas (see Figure 4).

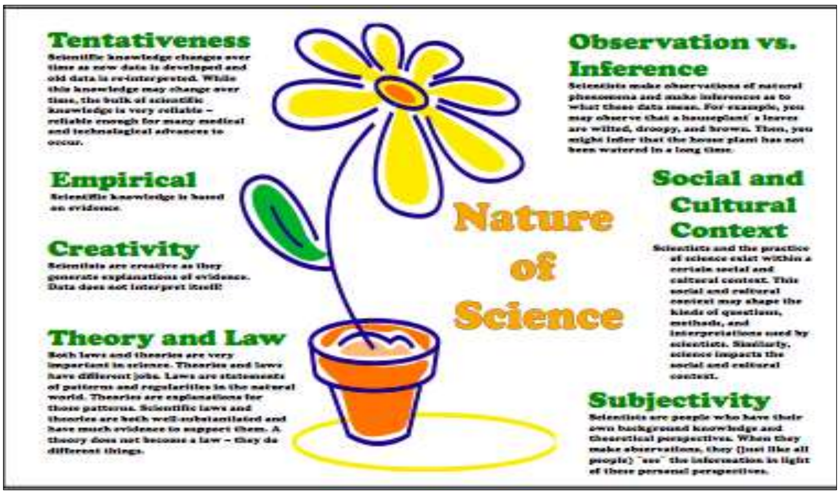

Figure 4. Aspects of NOS

In this way, students were able to reinforce NOS conceptions and reflect on how they figured out and interpreted aspects of NOS. Both being reflective and acting as scientist contributed to students' identity development of NOS. In the electricity unit, third graders were given opportunities to act as scientists who make observations, inferences and investigations. Being and acting as scientists contribute to students' NOS identity development. As students acted as scientist, they reflected on the science investigations as well as NOS ideas through drawings, writings and verbal statements.

Conclusion

The concept of identity is a valuable lens to use to examine students' learning. NOS takes a broad space in science literacy in terms of its contribution to students' understanding in content and approaches of science. In this study, as students engaged in a NOS embedded unit about electricity, they made more sense about what scientific knowledge was, how it was produced, and understood its connection to their daily lives. These connections may lead students to hold positive stances in understanding and learning science, and develop identities as future scientists.

In terms of specifics from this study, students progressed in their abilities to discuss NOS and use the terms associated with NOS aspects accurately. Their use of the NOS vocabulary, even in conversations among peers, indicated that they had developed identities as individuals with NOS as part of their repertoire. The teacher provided overviews of NOS for the students, and helped them make explicit connections to NOS aspects. These overviews and connections helped students identify these ideas as important ones to which to attend. The debriefings following the investigations also enabled students to reflect on NOS ideas after they had engaged in the activities (Author, 2019). This connection to NOS that was pre and post investigation further reinforced to students the importance of NOS, which aided in their identity development that NOS is important. Connecting NOS to other content enabled further NOS identity development as it showed the importance of NOS across other curriculum areas, such as writing and mathematics. Further emphasis of NOS through discussing these ideas aided students in conceptualizing NOS not only as a content area, but also as an area of which they had knowledge and expertise—such that they developed NOS identities.

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