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Abstract

Nature of science (NOS) is a critical component and should be part of all science lessons. It is critical to begin NOS instruction in the elementary grades, to help young children develop an identity as persons who can conceptualize NOS ideas. The purpose of this study was to explore third grade elementary students' Nature of Science (NOS) identities as a result of participating in a unit on gravity. The research question specifically was "How do third graders' NOS identities change as a result of participating in a unit on gravity?" Explicit reflective NOS instruction was embedded in a unit on gravity. Data included videotapes of the lessons including class discussions prior to and after the lesson, and use of children's literature. Other data included copies of student work and student science notebooks, and their presentations of work. Data were analyzed independently by three researchers for comparison of analysis. NOS identity development was found to be related to ideas that were "connections to real life," "class discussions of ideas," and "making connections to other science content." Students in this class were able to use and apply NOS terms accurately. Results support that elementary students can learn NOS through appropriate instruction.

Introduction

Nature of science (NOS) is considered a critical component of scientific literacy for all students (Michaels, Shouse, & Schweingruber, 2008). Understanding NOS is essential for understanding content and processes of science. It helps one to develop informed decision-making abilities for a student and it also helps students to learn science subject matter. Thus, teaching NOS to elementary students is essential. Developing students' understanding of NOS in early grades helps them develop better conceptual understanding of NOS and science content in later grades (Akerson, Buck, Donnelly, Nargund & Weiland, 2011). Studies have shown that elementary students do not naturally develop adequate understandings of NOS from inquiry instruction (Akerson & Abd-El-Khalick, 2005). However, elementary teachers can positively influence students' views of NOS with appropriate instruction such as making NOS connections within science instruction throughout the elementary grades (Smith, Maclin, Houghton, & Hennessey, 2000). It is also evident that if different aspects of NOS are discussed explicitly within the context of science or in a non-contextualized form, students develop understandings of these ideas. Akerson, Buck, Donnelly, Nargund and Weiland (2011) argue for including NOS in science instruction from the early grades to provide students with a foundation for learning about science content as well as NOS, predicting that students who begin learning NOS at early ages will have a better understanding of the science content they learn and develop better scientific literacy in terms of being consumers and producers of scientific knowledge over time. Indeed, high expectations for young children in terms of developing content knowledge about NOS are recommended. In addition, explicit-reflective NOS instruction has been found to improve NOS conceptions for learners as young as kindergarten (Akerson & Donnelly, 2010). Explicit-reflective NOS instruction includes drawing learners' attention to NOS aspects either through activities and discussions that are embedded in science content (contextualized in content) or as stand-alone activities and discussions that are targeted at introducing NOS elements to students prior to embedding in content (decontextualized from content).

Prior research has found that development of elementary teachers' identities as teachers of NOS is crucial for their conceptualization as well as instruction of NOS (Akerson, Pongsanon, Nargund, & Weiland, 2014). Could this also be one of the keys to aid elementary students in the development of their conceptions of NOS? The purpose of this study was to explore third grade elementary students' Nature of Science (NOS) identities as a result of participating in a unit on gravity. The research question specifically was "How do third graders' NOS identities change as a result of participating in a unit on gravity?"

Theoretical Framework

The concept of identity has increasingly gained attention from researchers in science education to understand students' engagement and learning in science classroom. According to Barton et al., (2013) " identity is a powerful construct for understanding student learning because identities are constructed through practice" (p.41). As a dynamic, and evolving concept, identity development ties to personal experiences and context (Akerson, Weiland, & Elcan, 2015).

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) that "refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge"(Lederman, 2007, p.833). NOS is multifaceted concept that includes the following aspects:
1) Scientific knowledge is reliable and tentative. It changes over time as new investigations occur. 2) It is built on empirical evidence. 3) It is derived from observations & Inferences. 4) Creativity, as well as social and cultural context play a role in the development of scientific knowledge. 5) It is subjective. Even though science is based upon empirical knowledge and objective elements, it always includes an element of subjectivity. 6) Both theory and law are important concepts in science.

Starting from age five, children can conceptualize aspects of NOS, and as they become older they show more development of NOS identity (Akerson & Donnelly, 2010). The rate of development of children's identity of NOS differs (Akerson & Donnelly, 2010). For instance, Quigley, Pongsanon, & Akerson (2010) found that some children who participated in informal science program still had inadequate views about some NOS aspects after instruction.

Children' conceptualization of NOS goes through from concrete concepts such as observation and inferences to more abstract concepts as subjectivity (Akerson & Donnelly, 2010). During this process, reflective instruction plays a critical role in the development of Nature of science identity. Students can reflect on their science investigations through drawings, writings and verbal statements.

We knew from prior research in informal settings with young children (e.g. Quigley, Pongsanon & Akerson, 2010) and in traditional classroom settings with older children (e.g. Khishfe & Abd-El-Khalick, 2002; Akerson, Nargund-Joshi, Weiland, Pongsanon, & Avsar, 2014) that the explicit-reflective approach is effective in helping children improve their conceptions of NOS (Khishfe, 2012; Khishfe & Lederman, 2007). We therefore elected to use explicit-reflective NOS instruction, embedded in the third-grade science content, to teach NOS aspects. While a review of prior research illustrates that children can indeed improve their conceptions of NOS given appropriate instruction, we desired to define the process of building third grade students' identities toward conceptualizing NOS.

Method

This qualitative study explored NOS identities as developed by a diverse third-grade class through a gravity unit taught through an explicit-reflective approach. Data were collected from several sources to develop pictures of students' NOS identities. In the sections below we describe the classroom interventions, data collection, and data analysis.

Intervention

This study took place in a public school in the United States. The context was a diverse third grade "at risk" (as identified by state regulations) classroom of 24 students studying a four week gravity unit. The goals for the unit were to teach about forces, have students compare gravitational force to other forces, and for students to conceptualize ideas related to gravity that were at their developmental levels. Other goals were to embed NOS aspects into the gravity 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 testing "masses" through the use of testing various shoes, mass of a sponge vs. bar of soap, building and exploring rollercoasters. Other activities included exploring push-pull forces as well as rotational force through the use of tops and spinning. In this lesson NOS was connected by the teacher asking students to make observations and inferences about which tops would spin faster. The teacher further asked them for their empirical evidence. The teacher further asked students to consider how they were acting like scientists. Students stated that they were "thinking creatively about data" and "making observations." One student stated, "We used our background knowledge about tops to make predictions." Comparisons were made of different forces by students. One activity they particularly enjoyed entailed thinking about how rollercoasters work, and designing and building their own models of rollercoasters. This activity enabled the teacher (first author) to connect the relationship between theory and law regarding gravity. The teacher (first author) was on sabbatical from her university position as an associate professor of science education, and worked full time in the fall semester in the classroom, while the regular classroom teacher was also present. The teacher was able to discuss theory and law with gravity through an article in a science magazine the students had discussed. In this particular article the students shared ideas about how Einstein's theory of relativity was being challenged by a new scientist who is studying explanations for gravity. The course teacher described law as being often a mathematical relationship about things observed, while scientific theory was a way to explain the relationship. The teacher further stated that it was similar to how an inference is the meaning someone makes of observations, theories are explanations we have for laws. In a subsequent lesson, students explored the relationship of ramp height and floor surface, along with toy cars that they could test along the ramps.

Students prepared reports regarding forces and gravity and made presentations to their classmates. Class discussions about gravity 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 gravity content knowledge as well as NOS content knowledge.

Data Collection

We used qualitative methodology through an interpretive approach (Bogdan & Biklen, 2003) to determine development of NOS identity. We used a variety of data sources that we collected daily over the four-week unit to ensure valid interpretation of NOS identity development. We video recorded daily science lessons that included pre-lesson discussions about gravity as well as NOS, daily activities and investigations, and class discussions at the conclusion of the lessons to determine any change in NOS or gravity understandings. Because the teacher often used children's literature to emphasize gravity content as well as NOS content, videotapes were made of discussions surrounding children's literature that were used in the lesson. The teacher maintained a teacher/researcher log of daily lessons, noting when and how she was teaching NOS and gravity lessons, and how she believed students were engaging and developing over the course of the unit.

Copies of student work were collected daily. The student work included their daily science notebook entries where students recorded data and also reflections on NOS and gravity content. At the conclusion of the unit the students made final presentations that included their ideas about gravity as well as their ideas about NOS. Written copies of their presentations were collected, as well as video recordings of their presentations were made.

Data Analysis

In line with interpretive data analysis, all three authors independently reviewed the data and met after their individual analyses to compare and discuss interpretations. While there were few disagreements, these were resolved through discussion and further consultation of the data. This procedure ensured valid interpretation of the data. Student data were blinded to maintain anonymity and to keep the first author who was also the instructor, blind to the identity of the students' work that she would help to analyze.

Data were independently reviewed to determine emergent categories indicating students' identity development. Videotapes and transcripts of videotapes were reviewed by all researchers and emergent themes were identified. Emergent themes included "connection to real life, "discussion to debrief," "adapt the curricula," and "connection to other content." These codes arose from review of the teaching videos, with the teacher log being used to ensure the teacher was indeed, focusing on NOS and the gravity content in order to aid in the development of NOS identity through the unit.

Further codes emerged from review of the student data regarding identity development. Some of these emergent codes were "NOS idea," "Student independently using NOS term," "students discussing NOS ideas in small groups." These codes arose from review of videos of interactions between teacher and students, as well as interactions among students. Additionally, review of the student science notebook entries were used to corroborate the emergent codes and track development of NOS ideas and identity throughout the unit. We tracked whether students were using NOS ideas accurately in their notebooks and in their conversations. We found they were accurately using these ideas, and that was evidence of their NOS identity development.

Results and Discussion

In the following section we describe findings from the study. First, we describe some of the teaching interactions that took place between the teacher and students that likely contributed to the third graders' NOS identity development. Next, we describe the emergent themes of influences on identity development.

Examples of Classroom Interactions

The teacher began the unit on gravity unit by reading a story "*I Fall Down*" written by Vicki Cobb. Before reading the story, the teacher showed the cover of the book and asked students to predict what the book was about. Students gave answers like " the kid is falling down," "baseball," and "science." After reading the first part of the book, the teacher introduced the topic of gravity to students and said that, " as long as you are on earth, you can not get away from it." Following this statement, the teacher stopped reading and had students participate in an activity.

In the activity, the teacher first held a penny and key and asked students whether they would fall down at the same time if they were dropped from the same distance. One student said "the coin will fall first, because heaviest fall down more fast," another student made a similar statement saying, "I think the heaviest one will fall down first, the key might fall down first, because it is heavy." Even though students had a disagreement about whether a penny or key was the heaviest, all seem to agree that the heaviest object would fall first. Second, the teacher told students to make observations and decide which one would fall first. The teacher dropped the penny and key from the same distance and students watched the teacher. Some students stated the penny fell first, others said the key. A few students argued that they fell at the exact same time. This activity illustrated that students used their subjective knowledge, which is one dimension of NOS in exploring gravity. Even though all students observed the same experiment, they have not stated the same results. This shows that students conceptualize scientific concepts in light of their subjective, background knowledge.

In the second activity, students were given five items including a sock ball, marble, penny, book, and paperclip and asked to compare which one would fall first. Using their creativity, students tried various experiments such as paper clip versus book or marble versus sock ball. In their investigations, students found " winners," or "losers" in each case; only two students said the result was a tie. Following this activity, the teacher read a part from the story and told the class that when they dropped a feather and a book, the result would be a tie, if there was no air. She then asked students "What do you think if we drop a book and a paperclip in classroom?"

One student answered, " I think the book will be the winner," and other students agreed. The teacher reminded them "gravity pulls everything with the same speed, so think about that." After a pause, one student commented, "it would be a tie." After this activity, students tried to make connections between mass and gravity. Following that the teacher held a sponge and a soap bar and asked students, "if we drop these from the same distance, which hits your hand harder?" All students assumed that "soap is heavier, and it hits harder." Students investigated and observed whether soap or sponge hit harder. After investigations, they all sensed that soap hit harder. The teacher then read another part from the book and explained that, "your weight is measure of how hard you fall down" and asked students "if you and a dinosaur fell, which one would be harder?" Students answered in chorus "Dinosaur."

During the gravity unit, the following poster showing aspects of NOS hung on the classroom wall. (See Figure 1) The teacher referred to this poster to help students conceptualize NOS elements prior to and following gravity activities. Students also referred to the poster when they were sharing their ideas. In this way, students were able to reinforce their ideas about NOS. In the last part of the session, the teacher drew attention to how theory and law work in science. She explained to students that scientists develop and use different theories to show how a scientific law works. As an example, she showed students a science magazine and talked about Einstein's relativity theory. She said, "Einstein tried to explain gravity (law) with his theory of relativity." She shared Milgrem's ideas about gravity. After these conversations, the teacher asked students "what does this tell about science?" Two students raised their hand. One said "background knowledge, scientists used their background knowledge to explain gravity."

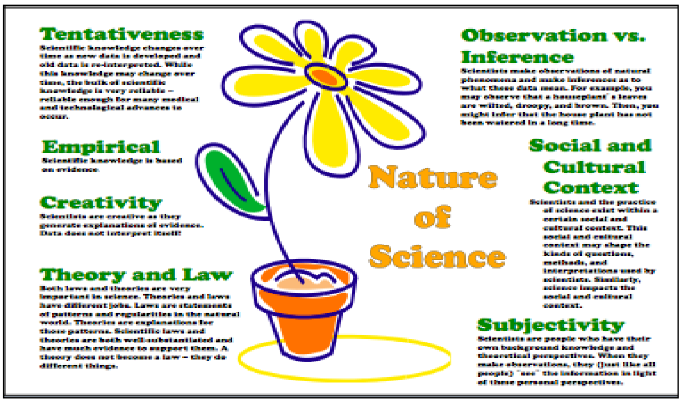

Figure1. Aspects of NOS

The second student commented, "This shows tentativeness." Students made sense that Einstein's theory seems best to explore gravity, the scientific law, but still other scientists are working on other theories showing how gravity works. In this way, students understood that scientists' knowledge continues to develop and might change with new evidence or reinterpretation of existing evidence. Though some students were better in understanding NOS concepts, they all showed improvements. During the activities, all students used their subjective knowledge related to how gravity might work and used their subjective knowledge in making interpretations. Using their imaginative and creative skills, students acted as scientist making observations, developing inferences, and designing investigations to explore gravitational force. Along with conceptualizing gravity content, students addressed aspects of NOS in great extent. This focus helped third graders to develop identities as persons who conceptualize NOS.

Influences on Identity Development

One strategy to encourage NOS identity development was to provide overviews of the NOS aspects that could connect to complex, yet real life topics, coded as "connection to real life." Rollercoasters were a real life concept that students had knowledge of, if not experience in riding. Adding the rollercoaster activity to the unit on gravity enabled students to connect scientific theory and law, as well as to share ideas regarding scientific creativity. Students realized that scientists used their background knowledge to create a roller coaster that would not only "work" but also be safe. The connection was then made to engineering and design. Students were aware that engineers designed the rollercoasters, and that they should "study science" to become engineers, as well as "build models" to test their ideas, which they stated was an "example of scientific creativity."

Another influence on NOS identity development was the discussions the teacher had with students to debrief activities, coded as "discussion for application." After each investigation the teacher held a discussion about the science content covered, as well as the NOS content investigated. For example, after the roller coaster investigation, the teacher discussed the NOS aspects that were related to the roller coaster activities. She asked the students whether they saw "observation and inference" used in their investigation. One student said he "observed that it needed speed to go up" to make the ramp steeper so the roller coaster would move. The teacher acknowledged that the ramp moving up was an observation, and "so the rollercoaster would move" was an inference. Students explained how they used their background knowledge (which the teacher connected to subjective NOS) to build their roller coasters. They also discussed how they used scientific creativity in their designs.

Another strategy to influence NOS identity development was found to be "connection to other content." This influence took place through connecting not only the science content of forces to NOS, but also using other school content to teach about NOS as well as forces. For example, three different children's books used in the unit were directly focused on the content area. These books were "*I Fall Down*" (Frazee, 2003), "*Rollercoasters*" (Cobb, 2004), and "*Sheep in a Jeep*" (Shaw, 2009). These books were used to set up and introduce activities, and to engage students in activities that were part of the story, as in the case of "*I Fall Down*." Additionally, students were asked to maintain science notebooks, in which they not only recorded ideas about forces, but also ideas about NOS. While students investigated forces, they also measured and counted, which included mathematics. In their final assignment, they discussed their ideas and developed a presentation about their ideas about gravity. They presented their ideas orally using a poster they designed. They described the evidence they used to develop their ideas. One example of their evidence was "if the ramp is flat, the jeep won't go," so we need to "raise the ramp." Another was "It goes faster on the tile and slower on the sandpaper. We think smoother surfaces make them go faster."

Conclusion

NOS is an important concept in scientific literacy in terms of its contribution to students' understanding of content and approaches of science, as well as the kind of knowledge science develops. In this study, as third graders engaged in a NOS embedded unit about gravity, they made more sense about origins of scientific knowledge, approaches scientists follow, and its connection to their own lives. These foci 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 understandings and vocabulary. 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 (Akerson & Donnelly, 2010). 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.

It was similarly important that students engaging in science practices (NGSS Lead States, 2013) and acting like scientists through taking part in the investigations helped students to understand the scientific content as well as NOS. Were students not actively engaged in investigations it would have been difficult, if not impossible, to debrief using the NOS aspects. 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. It was also clear that reading children's literature books and using the discussion about the books throughout the lessons made it possible to help students understand concepts better along with NOS aspects.

Using real life examples drew students' attention to the investigations, as well as to learning about NOS. For example, the topic of rollercoasters made it easier to discuss not only forces, but also NOS aspects, as students were so interested in the topic. Because they were interested in designing their rollercoasters, and they were highly engaged in the investigation, they had a better understanding at the end, which made it easier to debrief and discuss NOS aspects along with the content.

Recommendations

This study provides further support for explicitly teaching NOS to elementary students (Akerson, Nargund-Joshi, Weiland, Pongsanon, & Avsar, 2014). Additionally, it is recommended that NOS ideas are introduced and connected to scientific investigations in such ways that students conceptualize not only science content, but also the content of NOS. This connection reinforces to students the importance of NOS, to help them with their identity development. This reinforcement should take place as part of all science lessons so students develop an understanding that NOS is part of science, and in fact, is a scientific way of knowing.

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