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Experienced Teachers' Strategies for Assessing Nature of Science Conceptions in the Elementary Classroom

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Abstract This study explored the nature of science (NOS) assessments K-4 classroom teachers developed for measuring students' understandings of NOS elements. We used the Views of Nature of Science Questionnaire-Form VNOS-D2 (Views of Nature of Science Elementary School Version 2) and interviews to verify that teachers' conceptions of NOS were sufficient to enable them to teach and assess NOS. We collected copies of teachers' action research designs, lesson plans, and assessment tools, conducted classroom observations and made field notes of their science instruction and assessments. We videotaped conversations at monthly workshops to note discussion surrounding teaching and assessing NOS in K-4 classrooms. We found that experienced teachers designed a variety of strategies for assessing NOS conceptions that differed by grade level.

Keywords Elementary inservice teachers · Nature of science · Assessment

Developing appropriate conceptions of nature of science (NOS) has been deemed an important goal for K-12 education, particularly in terms of improving citizens' scientific literacy (Driver et al. 1994). Previous studies have found that elementary

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students can indeed improve their NOS understandings through appropriate instruction (Akerson and Donnelly 2010; Akerson and Hanuscin 2007; Akerson and Volrich 2006; Smith et al. 2000). However, it is also the case that these changes in student understandings were assessed using researcher-developed instruments. Teachers desire to have classroom-based assessments that would enable them to track any changes in students' conceptions of NOS (Akerson and Hanuscin 2007). Indeed, the ability to use formative assessment to inform future NOS instruction and summative assessment to determine NOS understandings is an important part of NOS pedagogical content knowledge (PCK; Schwartz and Lederman 2002). The purpose of this study is to explore the kinds of NOS assessments K-4 classroom teachers develop as they endeavor to measure their own students' understandings of NOS elements. In this paper we will describe assessment strategies designed and used by teachers as they conducted action research studies in their classrooms.

Literature Review

Our study seeks to explore K-4 teachers' development of tools to assess the NOS conceptions held by their students. Our goal was to see what kinds of tools they developed to assess their students and whether they believed those tools enabled them to understand their students' NOS conceptions. As such, we review literature on NOS as well as assessment.

Nature of Science

In their NOS position statement the National Science Teachers Association (NSTA; NSTA 2000) recommends that teachers and students know that (a) scientific knowledge is both reliable (one can have confidence in scientific knowledge) and tentative (subject to change in light of new evidence or reconceptualization of prior evidence); (b) no single scientific method exists, but there are shared characteristics of scientific approaches to science, such as scientific explanations being supported by empirical evidence, and are testable against the natural world; (c) creativity plays a role in the development of scientific knowledge; (d) there is a relationship between theories and laws; (e) there is a relationship between observations and inferences; (f) though science strives for objectivity, there is always an element of subjectivity in the development of scientific knowledge; and (g) social and cultural context also play a role in the development of scientific knowledge. These aspects of NOS were the focus of this study, but teachers of different grade levels focused on teaching different aspects, often based on the their predictions on students' developmental abilities and assessed different NOS aspects.

Researchers have explored K-4 students' NOS views in several studies over at least a decade (e.g., Carey and Smith 1993). For instance, Akerson and Volrich (2006) explored first graders' conceptions of NOS using the VNOS-D2, and noted that these students improved their understandings of NOS elements after explicit reflective instruction. Similarly, Akerson and Hanuscin (2007) found that elementary students of different grade levels improved their understandings of NOS

elements, and Akerson and Donnelly (2010) found that children as young as five were able to conceptualize various elements of NOS that are advocated by the NSTA position statement (NSTA 2000). Smith et al. (2000) used the Nature of Science Interview to determine what NOS understandings students could develop after being in a classroom with a supportive curriculum and teacher. However, these studies have assessed students' NOS conceptions using researcher instruments. So, while it is crucial to know whether students of elementary grades can improve their understandings of NOS, it is necessary for teachers to be able to assess their own students' NOS conceptions as part of their classroom practice, as they would any other content in science. Therefore it is necessary to explore the kinds of assessment teachers find useable at various grade levels.

There have also been studies of K-4 students that show that simply participating in inquiry science does not in and of itself help students improve their conceptions of NOS (Akerson and Abd-El-Khalick 2003; Khishfe and Abd-El Khalick 2002). What has been found most important in improving K-4 students' NOS conceptions is the use of explicit reflective instruction (Akerson and Donnelly 2010; Khishfe and Abd-El Khalick 2002). Explicit reflective instruction refers to drawing the learner's attention to aspects of NOS explicitly through questioning strategies, discussions, written work, and asking them to reflect on the science they are learning by thinking of those aspects and how their activities in science are similar to what scientists do. An additional component to explicit reflective instruction is specific assessment of NOS aspects that are targeted in instruction. This assessment is formative and indicates to the teacher which aspects students still do not understand so she can provide more explicit instruction. The teachers who participated in this program practiced explicit reflective instruction with their students, and also designed assessments that helped them identify areas that required further instruction.

The Importance of Assessment

Enger and Yager (2000) discuss the importance of assessment of "six domains of science," which organizes an assessment framework for science learning and experiences around six domains including concepts, processes, applications, positive attitudes, creativity, and the nature of science. They further note the importance of classroom-focused assessment in the context of instruction. In a 3-year study exploring teachers' assessment of students' science conceptions, Gearhardt et al. (2006) found that the experienced teachers designed classroom assessments that were both formative and summative and helped them to both conceptualize their students' science understandings as well as improve their science teaching by folding the information obtained from the assessment back into their teaching. Over time, the teachers in their study developed assessments that were more responsive to the students in their classrooms. It is obvious from these two studies that experienced teachers can design their own classroom-based assessment tools.

Though there are various researcher designed instruments to measure K-4 students' conceptions of NOS, most elementary science curricula do not include assessment of NOS conceptions and teachers may not find the research instruments

conducive to use in classroom practice (Akerson et al. 2009). Indeed, teachers in the current study reported that frustration. One group of teachers found that researcher developed instruments were too difficult to administer because they required multiple coders and the interview process required parental volunteers to help. Teachers are further constrained by their young students' developing abilities to write and to share their reasoning. However, teachers must assess other content areas, and despite these constraints, teachers desire to know the influence they are making on their students' understandings of NOS. If students are not developmentally ready to attain better understandings of NOS, then teachers would not want to spend their instructional time on NOS (Akerson and Hanuscin 2007). Teachers who have training and therefore the ability to teach NOS as part of their science instruction desire to know whether their instruction is making an impact on their students' conceptions of NOS, and therefore need to develop assessments that can be used in the classroom that take into account K-4 learners' reasoning, writing abilities, and their content knowledge. Additionally, to encourage teachers to be reflective practitioners they require opportunities to gain feedback on their teaching methods to be able to modify teaching methods and check for their own misconceptions in their teaching (Putnam and Borko 2000).

Bell (2008) devotes a chapter of his book to the assessment of NOS conceptions of K-8 students. He suggests a combination of formal and informal formative assessments, combined with summative assessments. He recommends using informal conversations with students to assess their NOS conceptions, and to use science notebooking as a structured formative assessment. He includes examples of researcher-developed summative assessments that are interview based and not easily used in a classroom. It remains necessary to determine teacher designed classroom-friendly methods of assessing K-4 students' conceptions of NOS throughout the instructional process.

Methods

This study explored the kinds of assessment tools K-4 elementary teachers developed to enable them to conceptualize their students' understandings of NOS elements. We used an interpretive model (Bogdan and Biklen 2003) with a variety of data sources that allowed us to discern distinctions and commonalities of assessment tools across grade levels.

Context and Participants

Participants were 10 K-4 inservice teachers in their second year of a 2-year professional development program. The first year of the program helped teachers improve their views of NOS through participating in science inquiries using *Physics by Inquiry* (McDermott and the Physics Education Group at University of Washington 1996) over a 2 week summer institute, and through classroom supports and monthly workshops, the facilitators helped the teachers improve their NOS teaching (Akerson et al. 2007). The facilitators were three university researchers in

science education with experience in designing and facilitating professional development programs for elementary teachers. Two facilitators had elementary teaching experience, and the third had high school science teaching experience.

In this program we endeavored to build a Community of Practice (CoP) that enabled teachers to refine their own NOS understandings, share teaching and assessment strategies, and receive feedback from their peers and project staff (Akerson et al. 2009). In the final year of the program the teachers designed action research studies on their NOS teaching practice. We used the book *The Art of Classroom Inquiry* by Hubbard and Power (1993) as a framework, but placed additional emphasis on NOS assessment. Hubbard and Power advocate helping teachers focus on not only reflecting on their practice, but thinking about their work in terms of data that can be collected to answer a question the teacher has about his or her own instruction. They discuss the importance of the classroom-focused research with research questions that are most meaningful to the teacher thus informing first the teacher, and then the field. The activities that were planned addressed the question: Now that you have incorporated some of the teaching strategies to teach inquiry and NOS in your science instruction, how do you know what the students are learning?" In their discussions the teachers talked about ways they noticed changes in their students, their engagement, and the kinds of questions they had in class. Other studies (Marcos et al. 2008) found that action research provided a good opportunity to encourage teachers to reflect and change their practice. While we initially planned to design NOS assessments to help the teachers, assessment ideas began being naturally discussed by the participants. This emphasis fit in well with the overall rationale for action research the teachers would carry out on their NOS instruction. The participants wanted to know if the work that they had been doing to improve their science teaching created a difference in their students' learning. They also wanted to be able to show the value of their new science teaching methods to their administrators and fellow teachers. That is to say, teachers are always engaging in formative inquiries about their own practice, but if they do not share their results, how can others learn from it? These formative inquiries were often tacit and a normal part of how teachers adapted learning experiences to fit their students' needs. They were part of day-to-day classroom operations and were often not examined or formalized into a shareable form. From their instructional designs, research designs, and designs for assessment of NOS conceptions, we were able to discern the kinds of assessments classroom teachers deemed usable and important in providing them information regarding their K-4 students' developing conceptions of NOS. See Table 1 for a listing of participants and their action research questions.

Data Collection

The three researchers used several data sources to explore the kinds of teacher-designed NOS assessments that were developed in this program. First, we used the Views of Nature of Science Questionnaire-Form VNOS-D2 (Views of Nature of Science Elementary School Version 2; Lederman and Khishfe 2002) and associated interviews of 30% of the participants to verify that teachers' conceptions of NOS were sufficient to enable them to both teach and assess NOS in K-4 classrooms. Next, we collected copies of teachers' action research designs, lesson plans, and

Table 1 Individual or small group action research questions

Teacher	Years of teaching experience	Grade level	Action research question
Michelle and Laura	10/31	Kindergarten	How does the understanding of five elements of nature of science change for full day vs. half day Kindergarten students through our teaching?
Hillary	2	1	What impact do the aspects of NOS have on students' beliefs, understandings, and enjoyment of science?
Barbara and Nancy	5/19	2	Through explicit teaching, can second graders learn four elements of NOS aspects (observation and inference, tentativeness, creativity, and empirical)?
Rosalyn and Betty	5/14	2 and 4	Does understanding the elements of NOS (observation/inference, tentativeness, empirical, and creativity) increase attention to detail in students' written applications?
Pat	18	4	How can explicit debriefing using literature support students learning concepts of Nature of Science when they are not explicitly discussed in the textbook?
Jacquelyn	1	Special Ed	What can students who are considered "learning different" articulate about their understandings of NOS?
Claudia	4	Special Ed	What can fourth grade students understand about NOS elements?

assessment tools. We conducted classroom observations and made field notes of their science instruction and assessments. We discussed and noted conversations we had with teachers about their action research projects, what changes they were making to initial plans, and any preliminary findings that began to emerge throughout the school year. We videotaped conversations at monthly workshops to note discussion surrounding both teaching and assessing NOS in K-4 classrooms.

Data Analysis

To discern that the teachers had adequate NOS content knowledge we reviewed their VNOS-D2 responses and associated interviews. Each researcher had previous experience coding the VNOS-D2 surveys. We each separately coded the responses as uninformed, adequate, or informed and compared analyses. There were very few discrepancies and any that arose were resolved through discussion, further consultation of the data, and consensus.

To describe the kinds of assessment strategies used at each grade level we reviewed lesson plans, and assessment tools, field notes of classroom observations, and the action research study plans being carried out in each classroom. We looked for NOS elements being emphasized and assessed in each class and grade level. We looked at lesson plans to discern whether there were NOS objectives as well as NOS assessments planned. We searched for patterns among assessment strategies across different grade levels to determine what similarities and differences could be found.

Table 2 Number of teachers who participated in the full professional development program with uninformed, adequate, and informed NOS conceptions

NOS aspect	Uninformed	Adequate	Informed
Empirical	0	14	3
Tentative	0	15	2
Creative and imaginative	0	9	8
Sociocultural and subjective (Theory laden)	0	7	8
Observation vs. inference	0	10	7

We reviewed videotapes to listen to conversations among teachers regarding assessment of NOS conceptions.

Results

From our analyses of the VNOS-D2 we found that all thirteen teachers held adequate or informed conceptions of all NOS aspects prior to teaching NOS in their classrooms. We know that holding adequate NOS conceptions is necessary, but does not guarantee NOS will be taught in the classroom (Akerson and Abd-El-Khalick 2003; Lederman 1999). See Table 2 for a breakdown of the NOS conceptions of all teachers in the program by aspect.

However, the teachers in this study were conducting their own action research studies and thus, were committed to not only teaching NOS, but to assessing the impact of their teaching on their students' NOS conceptions. Therefore we knew they would be teaching NOS to their students. In the following sections we will describe each teacher's strategies for assessing their students' understandings of the NOS aspects they targeted in their instruction, followed by an analysis of the similarities and differences in the assessment strategies across the grade levels, and assessment themes that arose in the action research studies. The studies are presented in grade level order, but many teachers shared similar challenges regardless of grade level.

Kindergarten Assessment Strategies

Two kindergarten teachers teamed up to design NOS assessments. One teacher, Michelle, had a half-day class (with 19 students in morning and afternoon), whereas Laura had a full-day class (15 students). They wanted to explore whether the amount of time spent on science lessons would make a difference in students' knowledge of NOS aspects. They revised the VNOS-D2 to their own VNOS-K version (see Fig. 1 for example) and used one on one interviews to assess if the students were learning NOS aspects. In addition, they used "driting," journals which are a combination of a drawing and writing, to encourage the recording of information at the child's developmental writing level. Finally, they had verbal debriefs of each NOS lesson and recorded field notes about what students were learning.

Fig. 1 Revised VNOS D2 (they called it the VNOS-K) that Laura and Michelle used with their kindergarten students. Revised VNOS-K consisted of the following questions: (1) Did we do anything in class that was science? What? (2) Can you give me any examples of what you think science is that you know about? (3) When have you used observation as a scientist? (4) How did using observation help you learn more about what you were working with? (5) When did you use inference as a scientist? (6) How did using inference help you learn more about what you were working with? (7) What do you see in this picture? (8) What could happen in this picture?

They discovered that it was difficult to assess kindergartners' learning, in general, partly due to their limited vocabulary and attention spans. For example, one teacher shared:

> In post tests, only about one-third of the children could tell me of a time that they used observation as a scientist and only half of them could verbalize how observation was able to help them learn more about what they were doing, I feel that they know what it means to observe something and to tell about that observation. (Interview, Michelle)

Interviewing kindergarteners proved difficult. The line between actual insight based on learning and imagination is sometimes blurred. Questions needed to be very concrete in order to focus students on a specific topic.

> I felt in some cases that the questions were a little too abstract for some of them to completely understand. But, when I showed them a picture they were all able to observe what they saw in the picture and tell me about it. When I went on and asked them what inferences they could make about their observations most had trouble responding. When I rephrased my question as "What could happen in this picture?" I got responses from all of the children that were possible and also made sense. (Interview, Laura)

Their overall reflection of the assessment was that all students showed changes in their answers from the beginning to the end of the year but with kindergarten students many of these differences could be accounted for with the developmental gains they naturally made during that school year. At the end of the year, teachers found that many more responses were on topic and that students could differentiate between two questions. They did find that students could understand the distinction between observation and inference, and in the future planned to make it an everyday part of the entire classroom experience not just for science. Students at this age often related to their most recent experiences and so responded well to short questions to assess a learning experience that had just happened. The teachers planned to make

observation and inference a daily part of processing all classroom experiences to increase its reinforcement.

First Grade Assessment Strategies

The first grade teacher, Hillary, chose three of the seven (observation/inference, creativity, tentativeness) nature of science aspects to better assess, which ones students learned (Akerson and Volrich 2006). Hillary faced the challenge of students who could not effectively write responses to questions. She used multiple methods to measure their NOS learning. First, she kept notes and did what she referred to as "kid-watching." She paid attention and noted what students learned and what they struggled with and adjusted her lessons. Next, after each lesson she gave students a short survey about what they had just learned. She used students' developing writing skills but also accounted for their difficulty with writing by creating NOS stickers that the students could use to communicate their learning (see Fig. 2 for example). Finally, she also interviewed each child in order to assess what they had learned both before and after the set of NOS lessons (see Fig. 3 for an example of questions she asked her students). She was able to assess that the students could use the NOS vocabulary as well as identify where they had used the targeted NOS skills. Hillary found that by triangulating the data she collected from different measures that students were better able to use the vocabulary and identify NOS in new science inquiry experiences.

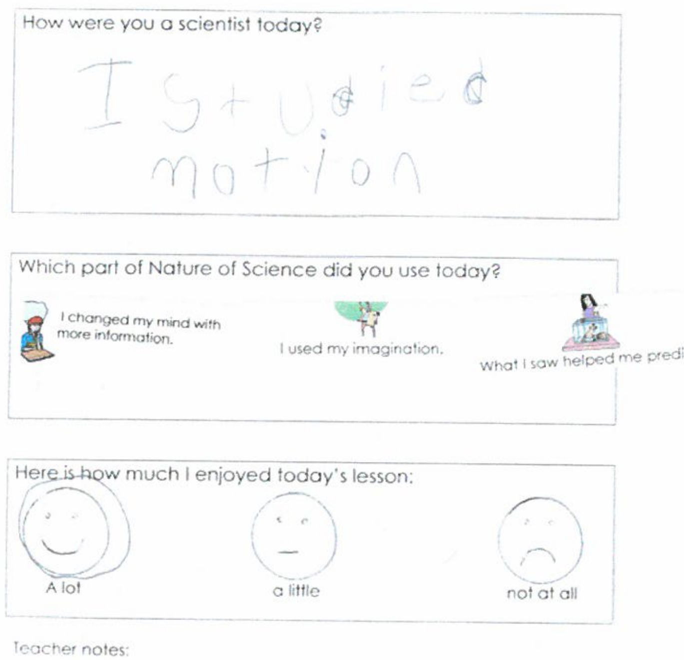


Fig. 2 An example of Hillary's first grade exit slips

Student Interview

Name ________________ Date _____ - _____- _____

Tell me what science is.

What is fun about science?

What is a scientist like?

Do you think scientists use their imagination? What do they imagine about?

Do you think scientists ever change their minds? What could make them change their minds?

Fig. 3 Interview questions for Hillary's first grade students

The teacher was confident with the data she collected. She interviewed the students in fall and spring, and was very reflective about the process. She explained how she appreciated how the students' ideas changed over the school year:

> I thought the fall responses to the interview were an indication of the kind of science experiences the children had in kindergarten (for example: mixing colors, "potions," and making food). It seems that students' spring responses showed they had a better idea of what science entails; such as doing experiments, making observations, and studying plants and animals. Some students understood the connection between imagination/creativity and dinosaurs (how humans have never actually seen a dinosaur; it is only through the study of dinosaur bones and living reptiles that we have an idea of what they looked like, and how imagination really comes into play regarding **dinosaur skin patterns and colors). I was gratified to see that some students** were able to relate tentativeness to problem solving. (Workshop Notes, Hillary)

Students reported enjoying science less later in the school year, which disappointed the teacher, however, she realized that she had been doing a lot of questioning and interviewing and wondered if the students had become fatigued. She found the most **difficult part was fitting NOS into an already packed curriculum but the experience** and the results of the assessment activities allowed her to plan for future years where she would present NOS before the science curriculum and stress it as a unifying theme as her students completed the adopted curriculum. She found that a mix of writing and using preprinted phrases useful in assessing NOS with emergent readers and writers was effective. However, in the future she planned to have phrases rather than pictures pre-printed as the novelty of the stickers were too tempting for some students who wanted to use all the stickers for each lesson. Overall, she felt that

multiple forms of assessment gave her useful information about what was happening in her classroom when she taught science. She spent much time reflecting on the data and planning for future teaching, and she reported growing more confident in her science teaching. It was the case for this teacher that she was able to assess her students' NOS views and use it to plan future teaching.

Second Grade Assessment Strategies

Difficulties with measuring learning were especially present in schools that had large English Language Learners (ELL) populations. For example, second grade teachers with a large number of ELL students (Barbara and Nancy) Barbara and Nancy wanted to investigate the question: "Through explicit teaching, can second graders learn the observational, inferential, empirical, tentative, and creative nature of science (NOS)?" From their own classroom experience, they felt that second grade students' ability to learn complex or abstract concepts was often underestimated. They relied heavily on explicit reflection (Akerson and Abd-El-Khalick 2003) making sure to debrief each lab activity. They used a variety of activities but started with those that were modeled by facilitators in the professional development program. They also included observation and inference booklets that the teachers made and students completed during each class activity. (See Figs. 4, 5, and 6 for examples of their assessment tools.) The lesson that matched the example in Fig. 6 asked students to explore solids and liquids. Prior to their investigation they needed to predict whether different substances, such as toothpaste, were solid or liquid. After

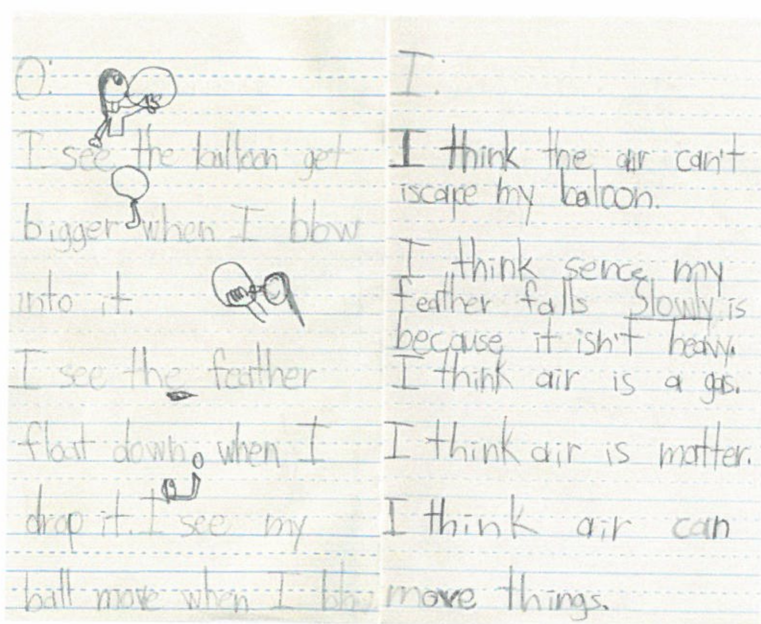


Fig. 4 Copy of Nancy's observation and inference journal used in second grade

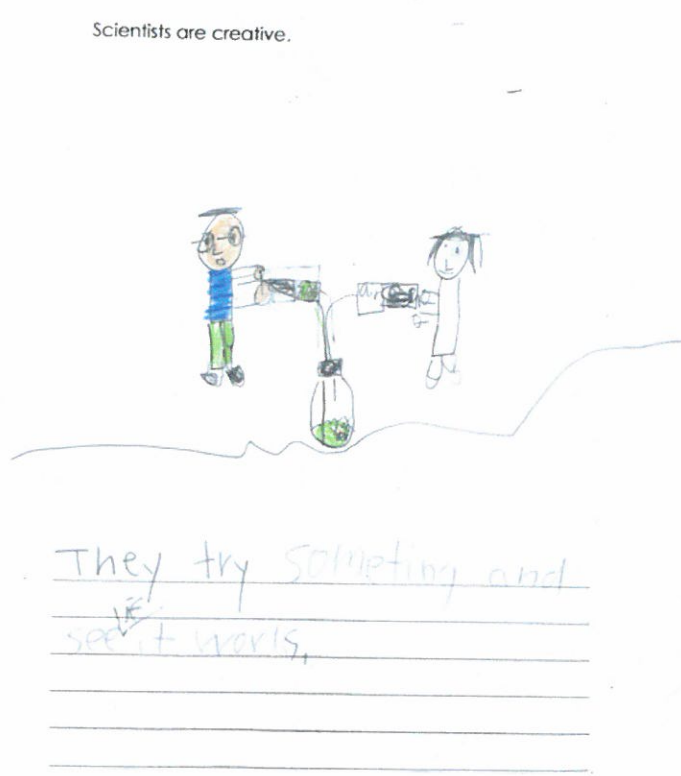


Fig. 5 Example of journal entry describing how scientists are creative in Barbara's second grade class

exploration they were asked to again comment on whether it was a solid or a liquid, and to reflect on whether they changed their ideas, and how that illustrated tentativeness. This written example of explicit reflective NOS instruction allowed the teacher to better conceptualize her students' understandings of tentative NOS.

Barbara and Nancy found that even at second grade, written responses to surveys were difficult to use to assess students' learning of NOS aspects. These teachers were in a school that was highly multicultural and many students spoke different languages at home. Instead, they found that by allowing students to use drawings along with writing, without penalty for spelling or grammar, students were able to better communicate what they were seeing in the activities.

Second and Fourth Grade Assessment Strategies

Two teachers paired up to design assessments at a rural school. Rosalyn taught a self-contained classroom of 17 fourth graders. Betty taught a similar classroom of 16 second graders. Betty's 16 second graders consisted of one student with an IEP and two students who were considered academically at-risk. The teacher team

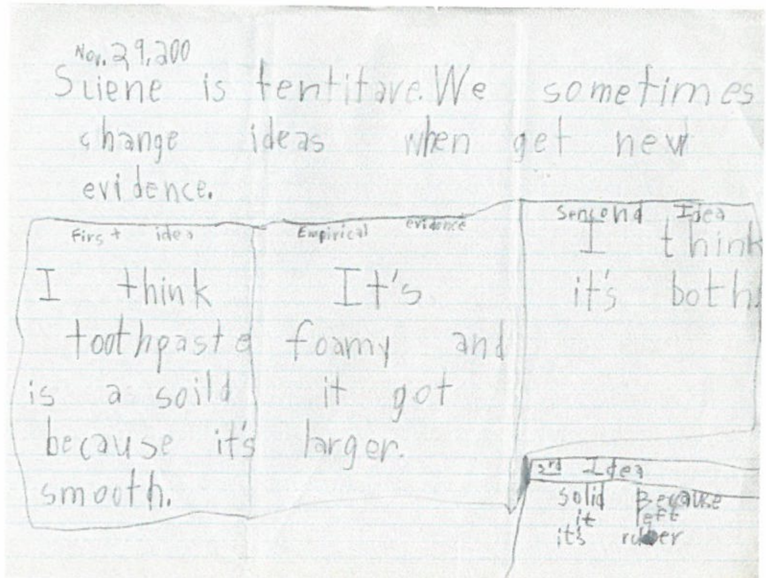


Fig. 6 Example of evidence and changing ideas journal from Barbara's 2nd-grade

analyzed state test data and found that students lacked detail in both their short answers as well as their drafts written to writing prompts. Because their school required teachers to emphasize writing and math above other curricular areas they decided to investigate if they could use science to encourage students to include more detail in their writing. They decided to choose certain NOS aspects that they felt emphasized detail and used them to build a bridge between science and writing, **specifically focusing on the detail the students were lacking. They used multiple data sources to measure student learning. They took field notes of their teaching.** They used surveys and interviews to gain ongoing knowledge of what students were thinking. Finally, they examined student work to observe changes in their writing using NOS aspects in their prompts. See Table 3 for an example of how they planned their alignment of NOS and writing instruction.

Before they began teaching they predicted that these NOS focused writing prompts would help students improve the detail in their writing. They scored their writing prompts using a 6 + 1 writing rubric as well as the writing prompt used for the state assessment test. A 6 + 1 Trait writing rubric is intended to help students develop their ideas and add detail in their writing (Culham 2003). **Students are** provided a 6 +1 writing rubric prior to their writing so they can know how they will be evaluated and what to include in their writing. The goal of this technique is to provide a common language for writing for teachers and students, a model for responding to students' writing, and a foundation for revision and editing. It allows students to become evaluators of their own work. Students were able to compare science and writing and used NOS aspects to help answer the questions. After scoring the second writing prompts using the 6 + 1 rubric, the teachers found that

Table 3 Example of Rosalyn and Betty's structure for NOS inclusion in science and writing

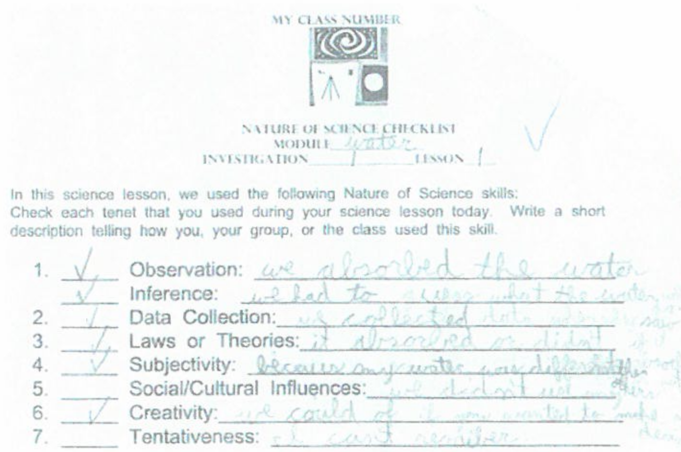
Lesson		
NOS tenets	Science	Writing
Observation	Use senses to collect data for work	Use senses to collect data for writing
Inference	Use observations to draw conclusions	Use details in writing to help readers draw conclusions
Empirical evidence	Collect data to use in work	Collect details to use in writing
Creativity	Use imagination to fill in missing data in work	Use imagination to create details to include in writing
Tentativeness	Always changing with new data and communication with other scientists	Always changing with revision and communication with other writers

all students showed improvement by including greater detail in their writing. Their state test scores did not improve, however. The teachers reviewed their results and decided that the rubric was far more focused on detail (their targeted skill) than the state scoring guide which may not be indicative of the student progress they were seeing in other measures.

Fourth Grade Assessment Strategies

Even for a fourth grade teacher whose students had better writing skills, there were challenges in how to assess students NOS understanding of all seven targeted NOS aspects. While fourth graders have better developed literacy skills, getting at their knowledge can still be difficult. Pat wanted to know what students had learned about NOS. She used multiple assessment strategies including exit slips that required students to not only identify NOS aspects that were used in a day's science experience but also provide a rationale for the choices that students made (see Fig. 7 for an example of this strategy). She recognized the importance of parental support in her students' learning and sent home a survey to parents about their own understandings of NOS aspects. In addition, she developed a series of scenarios that she read to the class and had them respond with their views of what aspects of NOS were present. See Fig. 8 for an example of a scenario. The cases served to stimulate classroom discussion and provide opportunities for students to discuss situations where different aspects might overlap or not be so clear.

Pat went beyond the classroom in her investigation by asking parents to predict where students might struggle and also encouraged students to predict which NOS aspects would be most difficult to learn. She found that parents could not predict the areas where students would struggle. She found that fourth graders had difficulty understanding some NOS aspects such as creativity and sociocultural NOS. She reflected:


MY CLASS NUMBER

NATURE OF SCIENCE CHECKLIST
MODULE
INVESTIGATION LESSON

In this science lesson, we used the following Nature of Science skills:
Check each tenet that you used during your science lesson today. Write a short description telling how you, your group, or the class used this skill.

1. Observation:
Inference:
2. Data Collection:
3. Laws or Theories:
4. Subjectivity:
5. Social/Cultural Influences:
6. Creativity:
7. Tentativeness:

Fig. 7 Example of exit slips Pat used in her 4th-grade class

> Many students assumed that someone who "did their best" was using creativity. Several students cited examples of someone acting something out **as being creative. Several answers identified by the students as cultural influences were, in actuality, examples of subjectivity. For instance, students would mark cultural influences as being present in the scenario and on the line** beside it would write, "She had been on similar rides in the past." Or "He had seen similar cases before." (Interview, Pat)

She found that she needed to present students with more examples and review terminology more often to be able to help them to understand the more abstract aspects. Students needed more concrete examples and opportunities to practice their skills.

Special Education Assessment Strategies

As classrooms include more students with different abilities, the challenge of assessing science learning becomes even more important. Jacquelyn was a special education teacher who had several students she supported in an inclusion classroom. She also endeavored to assess all conceptions of NOS and faced the typical **challenges in assessing NOS in an elementary classroom with the added difficulty of** students with varying abilities to communicate and explain their learning. She was interested in how the students' own beliefs about their abilities to do and enjoy science would affect their success in learning about science and NOS. To assess how students were learning NOS in the classroom she used four different tools. She used a standardized test SPAEMSS (Science Process Assessments for Elementary and Middle School Students; Smith 1999). **The SPAEMSS is a multiple-choice test** used to measure 13 science process skills. She also used the end of unit exam provided by her curriculum *Full Option Science System* (FOSS). She had students complete surveys measuring their beliefs toward science, and conducted interviews

Scenario #1: Early one morning, people who lived near Lake Timber noticed five dead fish lying along the lakeshore. They became worried and called Nancy a scientist, a hydrologist. Nancy visited the lake and made many observations and measurements. She had worked with other cases similar to this before and using this knowledge, began to think of possible cases for the death of the fish.

Her first idea did not match her evidence taken from the measurements. She began to look for other possible causes. She obtained a map of the area and noticed a new factory had recently opened upstream on the river that came into the lake. This factory was twenty miles away from the area from where she found the dead fish. She visited the factory and noticed that they used water from the river.

Nancy knew that many materials floated, sank and mixed with water and that different temperatures of water caused the water itself to float and sink. She took samples of the water and looked for temperature of the water and chemicals in the water after it left the factory. She found a very small amount of a very dangerous chemical in the water. She then looked and found that same chemical in the fish. The factory was asked to better treat the water after using it and the fish population was saved.

What Nature of Science Aspects did you recognize in this scenario? Write a few key words from the sentences that show this aspect as it appears in the story.

____Tentativeness______________________________

____ Subjectivity ______________________________

____ Cultural Influences ______________________________

____ Data Collection ______________________________

____Observation and Inference ______________________________

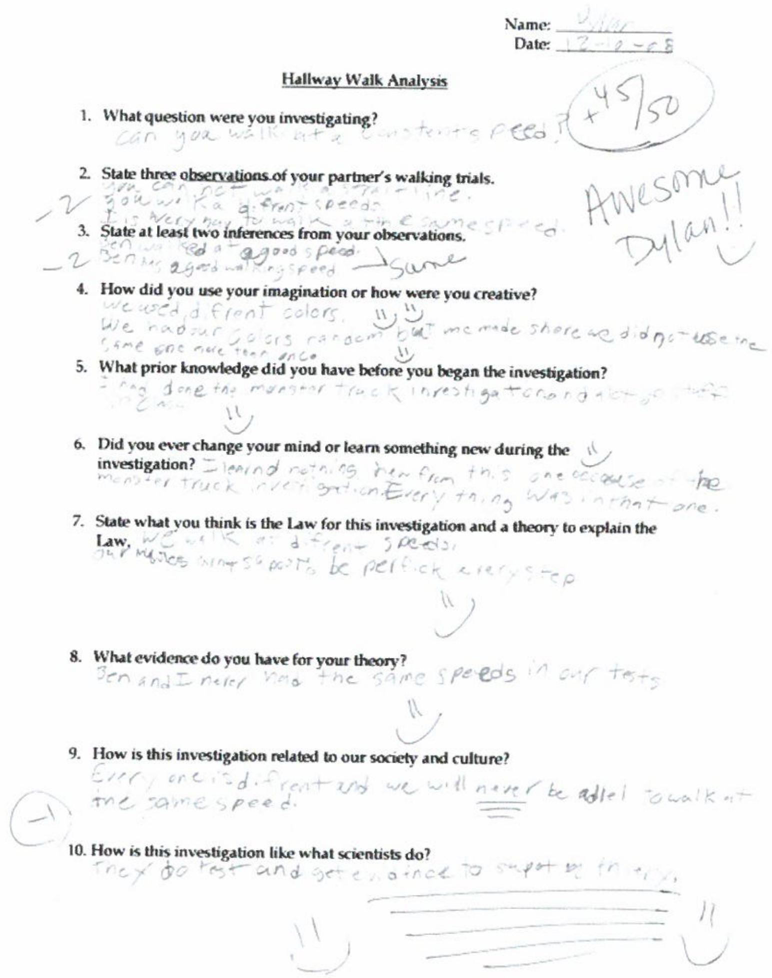
____Theory and Law ______________________________

____Creativity ______________________________

Fig. 8 Example of scenario used by Pat with her fourth grade students

before and after her NOS teaching. Finally, she also used the V-NOS D2 (Lederman and Khishfe 2002) as a pre/post measure of student NOS understandings. She found the VNOS-D2 easy to use in her classroom because she did a case study of just three students in her small class.

Jacquelyn found several interesting results in her study. She found that all students improved in their understandings of NOS but different students responded to different aspects—there was not a consistent improvement on any one NOS aspect. Her students demonstrated a change in beliefs, in that they believed that all students could do science, without needing any special aptitude. She had thought by incorporating writing and reflection into her instruction that student writing would improve, but she found that it did not. As part of her assessment of her own teaching she made predictions about how she felt her students would perceive science. This reflective activity not only encouraged her to examine her own preconceived notions but was also her attempt to practice NOS aspects in her own action research


Name:
Date:

Hallway Walk Analysis

1. What question were you investigating?
2. State three observations of your partner's walking trials.
3. State at least two inferences from your observations.
4. How did you use your imagination or how were you creative?
5. What prior knowledge did you have before you began the investigation?
6. Did you ever change your mind or learn something new during the investigation?
7. State what you think is the Law for this investigation and a theory to explain the Law.
8. What evidence do you have for your theory?
9. How is this investigation related to our society and culture?
10. How is this investigation like what scientists do?

Fig. 9 Examples of writing prompts for older students in Claudia's class

inquiry—making predictions, observing and making inferences based on evidence (the results of her assessments). She shared her results with her special needs' students' regular classroom teacher to help her see the value of inquiry-based instruction to all of her students.

Claudia also taught in a classroom of students with varying abilities and was teaching at a school for children with learning differences (dyslexia) so each child faced an extra challenge to academic success. Additionally, students were in a mixed age group for science instruction, combining grades 1–9 in a single class. She wondered how students could use NOS to better articulate what they were learning in science and what misconceptions they had about science prior to learning with a NOS framework. She used Mohr's (1995) suggestions for teaching students with

learning differences. For example, she provided oral and written directions and visual and auditory clues for direction and instructions. She also allowed extra time and broke work into shorter segments, so she could reinforce each segment and encouraged collaborative work to build on student strengths. She collected multiple data sources including using the VNOS-D2 (Lederman and Khishfe 2002) as a pre-post measure, interviews, and having older students complete writing prompts. She designed multiple strategies for assessment of NOS conceptions to enable her to differentiate her assessments as she did her instruction. See Fig. 9 for an example of Claudia's writing prompts for older students.

She found that that while NOS instruction provided a unifying theme for her units that assessments needed to be more diverse for her students. Her students varied not only by grade level, but also ability levels that transcended grade levels. She needed, designed, and used strategies that included checklists, oral conversations, and written work. She felt that her writing prompts for older students gave her more insight, and should have asked younger students to do different kinds of tasks to understand their beliefs and learning.

Discussion

In looking at the results of the teachers' assessment and research projects, we were able to identify several different themes. The teacher was a very important part of the research process and each of them had tacit knowledge about the students, their abilities and how best to assess them. They also reported that the assessment process provided them with opportunities for reflection that improved their teaching and increased the collaboration with others. Finally, the designing, implementing and analyzing assessments helped to reinforce the teachers' acquisition of appropriate NOS views by allowing them to see how skills like creativity, subjectivity, and the analysis of empirical data for decision making related to their own inquiry in a comfortable setting—their own classrooms.

Teacher as Classroom Expert

There were differences across classrooms that were tied to the individual students, their developmental levels, special needs, and their academic abilities. These various assessments demonstrate that students can learn concepts related to NOS but teachers' abilities to assess what they are learning may require a creative hand. In the few classrooms that we share in this piece, there were inclusive classrooms, stand-alone classrooms with children with learning disabilities, classrooms where a large majority of students were English Language Learners (ELL), and classrooms that included mixed-age groups. They represented a large variety of learner skills, and in all assessment activities there was a common theme—the teacher, with her knowledge of her students, content and classroom was a valuable instrument in assessing student learning (Shulman 1987). Teachers had knowledge of the learner and the content and were able to develop age and classroom appropriate assessments for their students, which is a critical element of PCK.

Teachers modified their assessments to best represent the developmental levels of their students. Pat assessed her fourth graders conceptions of all seven NOS aspects, whereas Laura and Michelle, Hillary, and Jacquelyn chose a subset of different aspects to focus on. The teachers of lower grades chose to focus on more evident NOS aspects like observation and inferences which seemed to match Pat's results with fourth graders in that they had difficulty with more abstract NOS concepts like the cultural NOS and theory and law.

Assessment methods were modified by the teachers both at the beginning of the project and throughout the semester. Expert teachers have characteristics that make them attuned and responsive to student achievement and learning (Palmer et al. 2005). In these examples we found this occurring in multiple ways. For example, Michelle and Laura changed the VNOS-D2 instrument to present more concrete examples and pictures for kindergarten students to respond to. They allowed answers to explain the spirit of the NOS concepts but were not held to specific vocabulary appearing in all responses as the vocabulary development of kindergartners varies greatly. In kindergarten and second-grade classrooms, teachers like Nancy and Barbara and Laura and Michelle adopted journaling techniques to allow students to use both writing and drawing to share their responses. Hillary used multiple methods including pictures, drawings, and writing to allow multiple opportunities for students to show what they had learned. All of these teachers, but especially Betty and Rosalyn, designed assessments that looked beyond standardized test scores to show how students were learning. All of the teacher participants were under enormous pressure to improve state test scores, but still assessed student NOS learning based on the students in their classroom and not on these external measures.

The Importance of Reflection

The teachers were highly reflective about their assessment activities. This reflection led to improved, more responsive teaching. The reflection provided motivation for some teachers. Hillary reported that by seeing the results of her study that she was looking forward to teaching science in the next year and would change her teaching based on the data. Jacquelyn was one of the teachers who used the assessment activities to challenge her preconceived notions about her students with special needs. She made predictions before she began teaching and used them to reflect on how her students were more capable and did not feel as disadvantaged to science success as she had thought. Developing reflective practice based on collected data is an important part of the national certification process and can not only lead to improved classroom teaching but also more satisfactory and relevant professional development plans for the teachers involved (Wagner 2006). Indeed, developing a reflective community of practice has been shown to improve teachers' instructional as well as assessment practices, developing teachers' individual identities and personal growth (Wenger 1998). We believe our community of teachers support this statement because through the professional development community they became more reflective as they shared their instructional and assessment strategies with each

other. They collected evidence for the value of their instruction on their own students' understandings which supported their change in teaching.

Teachers also reflected that this assessment activity helped them appreciate and value the collaboration with other teachers. Michelle and Laura reflected that having another kindergarten teacher to share ideas with was important for their thinking about NOS assessment. It allowed them to better adapt and keep on track. Michelle said:

> Laura and I were able to bounce ideas back and forth, along with working together to revise the interview instrument. We both experienced many of the same frustrations, setbacks and extra work that this project entailed. Toward the end, Laura was really good about keeping us on track so that we would get everything pulled together for our project. (Interview, Michelle)

Barbara and Nancy also reported that effective evaluation was difficult and having another teacher to help analyze ideas and interpret the feedback and translate it into practice was useful. Throughout the professional development we found that collaboration grew in its importance as teachers formed a community of practice where they supported each other in improved teaching (Akerson et al. 2009).

Practicing NOS Aspects in Classroom Inquiry

A third theme that we identified was that the planning, implementing and analysis of the assessment tools helped to reinforce teachers' own development of NOS conceptions. The process forced them to look at their practice and analyze it using empirical data and be creative in solving classroom problems to answer appropriate research questions. For example, teachers like Hillary, Barbara, and Nancy had to examine the kind of data that was appropriate to collect to understand student NOS understandings. They had to be creative in finding ways to allow all students to communicate their beliefs and both resorted to using pictures in different ways. In addition, several teachers (Jacquelyn, Pat, Laura, and Michelle) used predictions to drive their investigations. They made predictions about where they felt that students would struggle and then used empirical evidence as formative assessments for them to be responsive teachers and collect additional data throughout the school year. Creativity was evident throughout all of the assessment designs but definitely in Rosalyn and Betty's research question that looked at writing prompts. They had to creatively adapt their instruction and learning goals for students to allow science to exist within their district mandated writing emphasis. Pat showed a special sensitivity to the sociocultural NOS in that her design looked at the outside influences on student beliefs, namely their parents and used the research to engage the parents in the classroom inquiry.

An important part of their inquiry was teachers' plans for future instruction. This is recognized as a valid and powerful form of reflection (Marcos et al. 2008). All teachers talked about how they would teach in the future based on the data they collected. For example, Pat found that students in fourth grade need constant repetition of key terminology with which they might be struggling. Her future research would include additional repetition. Marcos et al. (2008) rated teacher reflections such as Pat's where teachers identified a concern, but also planned for

future teaching and reviewed their learning as highly desirable. Laura and Michelle similarly found that kindergartners require more frequent but shorter review of concepts tied to everyday occurrences to help them to use scientific thinking to make sense of their everyday events—especially observation and inference. This use of data from their assessment experiences for future teaching modeled the empirical NOS, a similarity that was not lost on the teachers. Many teachers reported that they felt better able to justify their science instruction, even with school mandates emphasizing literacy and math. They had the data to support that their instruction was making positive impacts on student knowledge.

Conclusions and Implications

The process of having teachers engage in classroom inquiry on their own NOS instruction reinforced their acquisition of informed NOS conceptions. It provided them an appropriate level of ownership and reflection that led to improved teaching and empowerment within their school communities. Additionally, it led to community development and greater feedback among teacher participants (Akerson et al. 2009). Though teachers were nervous at first, they enjoyed participating in the research process. They knew their classrooms well, how best to assess their students and were able to tailor both instruction and assessment to their students' unique needs. Many of these teachers continued to teach NOS and use their assessments beyond the support of the professional development team. In designing future professional development programs we recommend incorporating teacher input and collaboration into developing NOS assessments. We believe this attention to teacher knowledge will likely improve the results and empower the teachers and result in the development of teacher-friendly NOS assessments. Knowing they needed to discover the influence of their teaching on student knowledge provides them with a need to develop classroom-focused NOS assessments to track the influence of their teaching on their students' NOS conceptions.

As researchers, we learned much from working with the teachers in the professional development program and their solutions for classroom assessment. Added together, their teaching experience was over 100 years and that experience can be tapped by having the teachers suggest innovative ways to assess students. With appropriate support, teacher assessment measures that are often informal like kidwatching and journaling, can provide a valuable data source and new directions in understanding of both reformed based teaching practices and student acquisition of new science knowledge such as NOS.

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