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Professional Journals as a Source of Information about Teaching NOS: An Examination of Articles Published in Science & Children, 1996-2010

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ABSTRACT: Articles in the National Association for Science Teachers [NSTA] elementary journal *Science and Children* that describe an activity related to teaching nature of science [NOS] were analysed to ascertain the extent to which those activities align with research based suggestions for teaching NOS and the extent to which articles have potential for informing teachers' Pedagogical Content Knowledge [PCK] for teaching NOS. The results showed that the majority of activities focused on broad ideas such as "science as a human endeavour", whereas other aspects of NOS were emphasized less frequently or not at all. In terms of the potential of articles to improve teachers' PCK for NOS, we found authors included very little information relevant to teachers' knowledge of assessment of NOS and knowledge of learners. We suggest further study into the degree to which 'activities that work' (Appleton, 2006) from teacher professional journals may be a source of PCK.

KEY WORDS: Elementary education, nature of science, science education, science teacher education.

INTRODUCTION

Science education reforms in the United States strongly recommend that K-12 students should develop an understanding of the nature of science [NOS] to be scientifically literate (National Research Council [NRC], 1996; American Association for the Advancement of Science [AAAS], 1990). Substantial understanding of NOS allows individuals to understand science-based issues in their life, and to make informed decisions about those issues (Driver, Leach, Millar, & Scott, 1996). Despite these recommendations, there is a gap between policy and practice (Lederman, 2007). Research has shown that substantial understanding of NOS is not enough for teachers to transform that knowledge into the instructions that are accessible to their students (Lederman, 1999; Bell, Lederman, & Abd-El-Khalick, 2000).

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Science teacher educators have found that modelling NOS lessons can facilitate teachers' understanding of how to successfully integrate NOS teaching into their practice in ways that foster student understanding (Akerson & Hanuscin, 2007). However, such efforts may not be feasible on a larger scale; it would be difficult to model effective instruction of all NOS aspects in all teachers' classrooms. Fortunately, professional journals are a widely available resource for teachers, and there is a potential that articles that provide models and examples of effective NOS teaching can serve as a means for teachers to envision effective instruction (Smylie, 1989).

Articles in professional journals can provide a glimpse into the classroom of others, and supply teachers with a repertoire of activities to implement in their own settings. These are commonly utilized in teacher education settings, as well as in self-directed professional development activities of teachers (Jagger & Yore, 2012). For instance, Appleton (2002) described how elementary teachers seek "activities that work" for use with their students and found these were an important scaffold for the development of teachers' Pedagogical Content Knowledge [PCK]. Appleton (2002) adopted the phrase "science activities that work" because this was the terminology used by elementary teachers to describe classroom-tested activities which work best for teaching specific topics. Thus, grounding on the theoretical assumption that the practitioner articles can be a resource for improving teachers' PCK, this study aimed to understand to what extent articles published in Science and Children provided opportunities for elementary teachers to develop their PCK for teaching about NOS in their classrooms.

Researchers have examined practitioner journals to understand the way in which inquiry is enacted in everyday science classrooms (Asay & Orgill, 2010) and to examine the use of evidence-based-practices in supporting science literacy for all (Jagger & Yore, 2012). Yet, despite a proliferation of research on teaching and learning NOS (see Lederman, 2007) we know little about the extant practitioner literature in regard to NOS. Do practitioner articles provide teachers with appropriate models of NOS instruction and relevant information that can inform their PCK?

In this exploratory study, we examined articles in the elementary-level practitioner journal *Science and Children*, published by the National Science Teachers Association (NSTA), to identify potential "activities that work" for teaching NOS. By understanding the current pool of articles available to teachers, we can explore potential gaps that exist in translating current NOS research into practice as well as inform editors, authors, reviewers, and teacher educators about the status and implications regarding practitioner literature in this area.

BACKGROUND FOR THE STUDY

The Conceptual Ground for the Study (Pedagogical Content Knowledge)

Shulman (1987) described PCK as the specialized knowledge that distinguishes teachers from subject matter specialists—it is the knowledge that enables teachers to transform their subject matter knowledge into forms that are accessible and attainable by learners. Extending Shulman's ideas, Magnusson, Krajcik and Borko (1999) proposed a transformative model of PCK which is comprised of 1) orientations toward science teaching; 2) knowledge and beliefs about science curriculum; 3) knowledge and beliefs about students' understanding of specific science topics; 4) knowledge and beliefs about assessment in science; and 5) knowledge and beliefs about instructional strategies for teaching science. Based upon this framework, it is obvious that teachers should have knowledge as well as substantial understanding of NOS to be able to teach NOS in their science classrooms. This includes understanding how inquiry based teaching approaches can provide a context for incorporating NOS into science classrooms; knowledge about students' understanding and difficulties regarding NOS concepts and how to assess their ideas before, during, and at the end of instruction; and understanding how to design and implement explicit and reflective NOS instruction. However, development of such specialized knowledge for teaching NOS takes time and requires support for teachers (Akerson & Hanuscin, 2007).

There are various aspects that contribute to teachers' development of PCK such as observation of classrooms as a student and as pre-service teachers, personal classroom experiences, teacher education programs, and coursework in science (Grossman, 1990). In addition, Appleton and Kindt (1999) found recommendations from colleagues as another source for elementary teachers' PCK for science. Also, Appleton (2002) proposed "activities that work" as another possible resource for developing elementary teachers' PCK. Appleton uses this phrase to refer to the science activities that teachers seek from other more experienced colleagues to teach topics about which they have limited knowledge or teaching experience. Thus, given teachers' limited understanding of NOS and their lack of knowledge bases for teaching NOS, we believed "activities that work" could be useful in scaffolding the development of teachers' PCK for NOS. While Schwartz and Lederman (2002) have cautioned that providing teachers an activity pack of NOS lessons may encourage teachers simply to rely on these rather than developing their own instruction, Akerson and Hanuscin (2007) found that, at least initially, teachers require models of effective ways to teach NOS and must build a repertoire of NOS activities before they can innovate and modify their own curriculum materials to incorporate NOS. Thus, we believe that articles in practitioner journals such as Science and Children, published by the National Science Teachers Association, can be an important source of information and 'activities that work' that could help teachers develop their PCK for NOS.

The Conceptual Ground for the Study (Nature of Science)

The "nature of science" (NOS) has been identified as a critical component of scientific literacy in many science education reform documents (AAAS, 1993; NRC, 1996) as well as in a position statement of the NSTA (2000). NOS encompasses the epistemology and sociology of science or values and beliefs found in scientific knowledge and process (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Commonly-cited aspects of NOS relevant to K12 classrooms include that scientific knowledge is tentative, empirical, and subjective; science is a human endeavour which is involving with imagination and creativity; science is socially and culturally embedded; science contains no universal method for doing science; and science involves relationship between observations and inferences, theory and law (NSTA, 2000).

In general, K12 students do not have informed ideas about NOS (Abd-El-Khalick & Lederman, 2000; Lederman, 1992). Furthermore, research has shown that teachers may not have adequate understanding about NOS (e.g. Abd-El-Khalick & Lederman, 2000; Schwartz, Lederman, & Crawford, 2004). Although it may seem reasonable that engaging learners in inquiry learning experiences that reflect the practices of science would help them develop informed understanding about NOS (e.g. Scharmann & Harris, 1992), research has shown that simply engaging in scientific inquiry is not sufficient in itself to promote informed understanding of NOS (Schwartz, Lederman, & Crawford 2004; Abd-El-Khalick & Lederman, 2000). Rather, there is a widely documented need to engage learners in explicit and reflective instruction for them to develop adequate understanding of NOS (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman 2000; Khishfe & Abd-El-Khalick, 2002; Akerson, Hanson, & Cullen, 2007).

Khishfe and Abd-El-Khalick (2002) explain that explicit instruction is "meant to highlight the notion that NOS understandings are cognitive instructional outcomes that should be intentionally targeted and planned for in the same manner that abstract understandings associated with high-level scientific theories" (p. 555). In terms of reflection, students should be given opportunities to reflect on their ideas about NOS and how the activities in which they are involved in science classes are representative of how science works (Akerson & Hanuscin, 2007). In other words, students should be provided opportunities to compare what they do in science classroom activities with what scientists do.

Given the above, it is clear that teachers need more than an understanding of NOS in order to teach NOS. Abd-El-Khalick and Lederman (2000) propose that effective teachers of NOS should also have:

> *"…knowledge of a wide range of related examples, activities, illustrations, demonstrations, and historical episodes. These components would enable the teacher to organize, represent, and present the topic for instruction in a manner that makes the target aspects of NOS accessible to pre-college students. Moreover, knowledge of alternative ways of representing aspects of NOS would enable the teacher to adapt those aspects to the diverse interests and abilities of learners.... [T]eachers should be able to comfortably discourse about NOS, design science-based activities that would help students comprehend those aspects, and contextualize their teaching about NOS with some examples or 'stories' from history of science."* (pp. 692-3).

In other words, teachers need to have robust pedagogical content knowledge (PCK) for teaching the nature of science.

According to recent perspectives, NOS is viewed as a cognitive outcome of instruction (Abd-El-Khalick, 2001) and analogous to other topics in science which a teacher might teach (Lederman, 1998). Considering this, we used the PCK model proposed by Magnusson et al. (1999) as a framework for the present study. Specifically, we sought to identify information in practitioner articles that describe activities for teaching NOS or specific aspects of NOS that would be relevant to informing teachers' knowledge of learners, assessment, instruction, and curriculum. The specific research questions driving our study were:

- To what extent do articles published in Science and Children provide appropriate models for teaching various aspects of NOS to elementary students?
    - What aspects of NOS are addressed within the articles published in Science and Children?
    - Within these articles, how does the instruction align with research-based practices such as explicit instruction?
    - To what extent are these activities shared by authors who would be considered "credible peers"?
    - To what extent do these activities provide models for teaching NOS at various grade levels, K-6?

- To what extent do articles published in Science and Children provide explicit information that can support elementary teachers' developing PCK for NOS?
    - o What kinds of information are provided regarding curriculum, instruction, assessment, and learners?
    - o How well do articles provide information in each of these areas?

METHOD

Data Sources

We analyzed the articles published in Science and Children since this journal is intended for an audience of elementary teachers. The NSTA website (http://nsta.org) provides a digital archive of articles as portable document (PDF) format –published as early as 1996. Even though NOS is emphasized in policy documents as early as 1990, such as Science for All Americans (AAAS), we assumed that teachers would not easily be able to access the articles published between 1990-1995-since the NSTA's archive doesn't include that period.

In a keyword search of the electronic archive and examination of the article abstracts, we identified 32 articles related to NOS in Science and Children. These were published between the years of 1996-2010. Of these, we decided to exclude 8 of articles because those articles either didn't explicitly address a specific NOS learning outcome, or didn't contain an example activity or strategy for teaching NOS (i.e., they did not provide an "activity that works"). Our criteria for inclusion are further illustrated in Table 1. Based on this, the final sample for our analysis included 24 articles.

Data Analysis

Articles in our sample were first examined to note authorship (e.g., whether written by a classroom teacher, science teacher educator, etc.). We then conducted a conceptual analysis of the content of the articles with phrases serving as the unit of analysis. Each of the aforementioned aspects of NOS emphasized in the reforms was used to guide the analysis. However, we were open to identification of additional or different aspect of NOS explicated by the article author(s). Our initial list included the aspects of NOS that are emphasized in the NSTA Position Statement on Nature of Science (2000):

- Scientific knowledge is both reliable and tentative; or subject to change

Table 1. Criteria for inclusion in analysis

Criterion	Criterion description	Example of Articles that meets criterion
Provided an 'activity that works'	Detailed description of what actually happened in a science classroom; not suggestions for teaching NOS or conceptual explanations of NOS.	For instance one of the analyzed articles described the activity as "On the first day of school, I give students a blank sheet of paper. On one side I ask them to draw a scientist, as done in the Draw-a-Scientist test" (Cavallo 2007).
Focused on learning science and/or nature of science	One of the main purposes of the activity was teaching the nature of science.	The authors clearly described their nature of science objective as "As we teach, it is important not only focus on science concepts and inquiry skills, but also to help children understand that science is a human endeavor to make sense of the world" (Sickel et al. 2010).

- No single "scientific method" adequately portrays the diverse methods and means by which scientists study the natural world
- Creativity is vital to scientific endeavor
- Scientific explanations must be based on evidence, and preclude supernatural elements
- Scientific knowledge is inferential; observations are interpreted with theory
- Scientific knowledge includes theories and laws, which have distinct functions and relationships
- Scientific work always has an element of subjectivity
- Scientific work is influenced, to some extent, by the social and cultural content of the work

An additional aspect of NOS emphasized in the articles and identified during our analysis included the idea that science is a human endeavor, and involves many different kinds of individuals.

We first coded each article based on the presence of each of these NOS aspects, rather than the frequency with which each aspect was mentioned in the article. The first author coded all data, and the second author served as a peer debriefed. To establish the validity of the coding schema, we coded the same article independently, and then met to resolve inconsistencies and make necessary modifications to the coding schema. We focused both on identifying the authors' explicit mention of a specific aspect of NOS as a learning goal of the activity, as well as identifying whether this NOS aspect was made explicit within the activity itself.

The same process was repeated in a round of conceptual analysis focused on identifying relevant information in each of the articles that could inform teachers' developing PCK for NOS. Magnusson et al.'s (1999) model for PCK was used as a lens for this analysis; however, we only analyzed the articles in terms of knowledge of curriculum, knowledge of learners, knowledge of assessments, and knowledge of instructional strategies for PCK, and refrained from making inferences about particular orientations toward teaching NOS of the authors, as we felt this was largely implicit in their writing. Upon completion of coding articles for aspects of NOS emphasized and components of PCK addressed, we tabulated the data to examine frequencies and patterns within and across articles, as well as across time (the number of articles published in different years).

FINDINGS

Articles as Sources of 'Activities that Work'

Our first research question was concerned with the extent to which articles in our sample provide appropriate models for teaching specific aspects of NOS. 'Activities that work' are selected by teachers based on a gap in their PCK for teaching particular topics (Appleton, 2002). Therefore, our first consideration was identification of the specific aspects of NOS addressed in each of the articles. Considering that one article typically emphasized one or more aspects of NOS, Table 2 shows the percentage of articles that emphasized each aspect. Analysis revealed that the majority of articles (75%) emphasized the idea that "science is a human endeavor". Given NSTA's author guidelines request that authors make an explicit link to the National Science Education Standards, this is reflective of the emphasis in the NSES Content Standard G for grades K-4, which states:

> *Through the use of short stories, films, videos, and other examples, elementary teachers can introduce interesting historical examples of women and men (including minorities and people with disabilities) who have made contributions to science. The stories can highlight how these scientists worked—that is, the questions, procedures, and contributions of diverse individuals to science and technology. In upper elementary grades, students can read and share stories that express the theme of this standard—science is a human endeavor* (NRC, 1996, p. 141).

Table 2. Frequency of Aspects of NOS Emphasized in *Science & Children* Articles (N=24)

NOS Aspects	Total Number of Articles (%)	Example Excerpts from the Articles Analyzed
Science as a Human Endeavor	18 (75.0)	"'Well, what does a scientist look like?' I asked. My students shared descriptions of lab coats, goggles, microscopes, and little old men with wire-rimmed glasses. Thus began our exploration into who scientists are and what work they do." (Lovedahl & Bricker, 2006, p.38)
Empirical	4 (16.7)	"We specifically set out to help students understand that sound is produced by vibrating objects (science concept), help students make and use observations to construct an explanation (inquiry skill), and help students understand that scientific explanations are evidence-based (understanding about scientific inquiry)." (Sickel, Lee, & Pareja, 2010, p.59)
Inferential/Theoretical	5 (20.8)	"Challenge the students to determine why they think the rings show different widths: What may have happened in the environment to create such a pattern? It is important to point out to the students that they are now making inferences based on their observations." (Rubino & Hanson, 2009, p.23).
Methods of Science	3 (12.5)	"Real science is creative; conducting an investigation may not lead to the development of new knowledge; planned investigations may take a different path as the researcher learns new things; scientists rarely work alone; and their work is not as linear as the scientific method suggests." (Olson & Cox-Peterson, 2001, p.43)
Tentativeness	3 (12.5)	""Could some finding be brought forth tomorrow that would change our current thinking about some scientific theory?" "Has a shift in scientific theory/understanding ever happened in the past?" These questions provide the opportunity for me to introduce examples from the history of science, such as the Earth-centered versus Sun-centered view of the solar system." (Cavallo, 2007, p.40-41)

Table 2. (cont'd) Frequency of Aspects of NOS Emphasized in *Science & Children* Articles (N=24)

NOS Aspects	Total Number of Articles (%)	Example Excerpts from the Articles Analyzed
Subjectivity	5 (20.8)	"…scientific knowledge is subjective. Scientists' previous knowledge, training, experiences, and expectations influence their works and affect the problems scientists decide to investigate, how they conduct their investigations, and how they make sense of and interpret their observations." (Lederman, 2005, p.53)
Creativity	2 (8.3)	"One aspect of nature of science that is hard for students to understand is how scientists use their creativity in science. Students can begin to understand how scientists can put their ideas and data together in unique ways or use their creativity and background experiences as each story is different, although the evidence is the same." (Rubino & Hanson, 2009, p.24)
Theory/Law	0	None of the articles emphasized this aspect
Sociocultural	0	None of the articles emphasized this aspect

The inferential nature of science and subjectivity were the second most emphasized aspects in the analysed articles. Almost 21% of the analysed articles both focused on the difference between observation and inference, and subjectivity aspects of science. In contrast, the relationship and function of theory and law and sociocultural aspects of NOS were two aspects that none of the analysed articles focused on. This is not surprising, given this particular aspect of NOS is typically not addressed in the elementary curriculum

"Activities that work" are called so by teachers because they are found to be effective in helping students learn (Appleton, 2002). Therefore, a second consideration in our analysis was whether the way in which articles emphasized these aspects of NOS reflects research-based recommendations for explicit and reflective instruction. That is, while the article may have explicitly identified a NOS learning goal, we were concerned with whether this learning goal was specifically planned for, taught, and assessed in the activities. Just under half of the articles (11 of 24) included an explicit emphasis on aspects of NOS within the activity described. Extensive research has shown the effectiveness of an explicit approach to improve learner' understanding of NOS (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000). In an explicit approach, the teacher draws students' attention toward particular aspects of NOS through activities. In other words, explicit NOS instruction doesn't assume that students would discover knowledge by themselves. For example, in one of the analyzed articles, the authors used tree rings as a context for presenting the difference between observation and inference. Before beginning the activity, students were provided necessary information such as how to interpret the light and dark areas in the tree rings to be able to make inferences about what caused those areas to be formed. After this initial instruction, the students were given a hypothetical ring tree and asked what happened that hypothetical tree's environment. The students then came up with the inferences based upon their observations. Following this, the instructor asked students to consider how scientists make inferences based upon their observations and whether these inferences are influenced by scientists' background knowledge, culture etc. (Rubino & Hanson, 2009).

As shown in Figure 1, an explicit approach for teaching NOS has been more prevalent since 2005. This may correlate with the publication of studies supporting the effectiveness of this approach on development of learners' understandings of NOS (e.g., Abd-El-Khalick & Akerson, 2004; Akerson, Hanson, & Cullen, 2007; Akerson, Buzzelli, & Donnelly, 2010). However, it is important to note that articles showcasing activities that utilize implicit approaches for teaching NOS appear in Science and Children articles, even in later years.

'Activities that work' are typically chosen by teachers based on the recommendation of a credible peer (Appleton, 2002). Therefore, a third consideration was examining whether the articles were written by elementary teachers' own peers (other elementary teachers) or others. Within our sample, we found the majority of articles were written by people such as science education professors, science professors, and graduate students in science education.

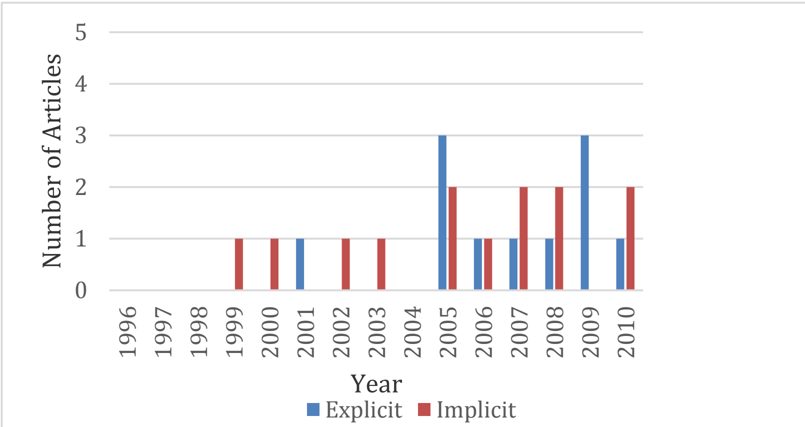

Figure 1. Articles Using Explicit vs. Implicit Approaches (N=24)

Figure 2, below, shows the proportion of articles written by or in conjunction with elementary teachers, versus those written by other educators. Only four of the 24 articles (17%) were written by science teachers.

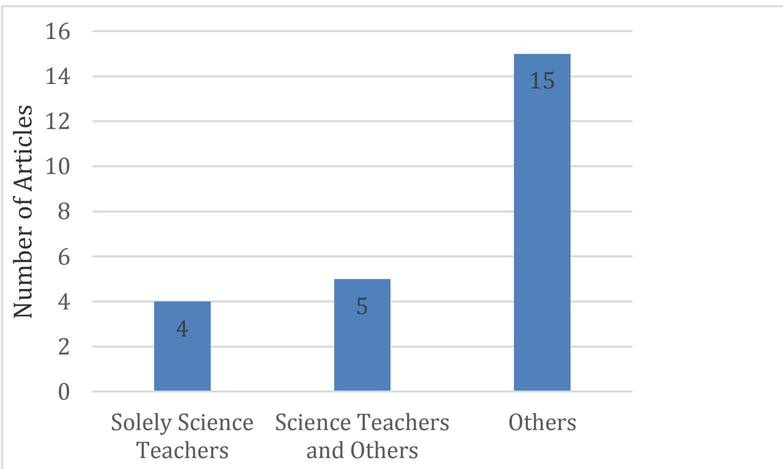

Figure 2. Authorship of Articles Analyzed

Jagger and Yore (2012) similarly found a disproportionate number of articles written by teacher educators vs. teachers in NSTA journals. The low number of articles written solely by elementary classroom teachers may suggest that the teaching of NOS does not receive high priority in elementary science, or may reflect research that shows few teachers understand NOS; however, it may simply be the case that elementary teachers are not choosing to write for Science and Children, particularly since they are not subject to the same pressures to publish that academics are.

As teachers search for 'activities that work', they are seeking activities appropriate for their students. Thus, another focus of our analysis was examining the extent to which articles provided models for teaching NOS to students throughout the elementary grades (K-6). As shown in Figure 3, most of the NOS activities in the articles we analyzed were intended for upper level elementary students (grades 5-6). It is important to note that analysis was based on what is stated in the articles about grade levels. For instance, some of the articles specifically stated their grade levels audience as 3rd or 4th. However, many simply stated a range of grade levels, such as K-4. Thus, an article focusing on K-4 is represented in Figure 3 both in the K-2 and 3-4 groups.

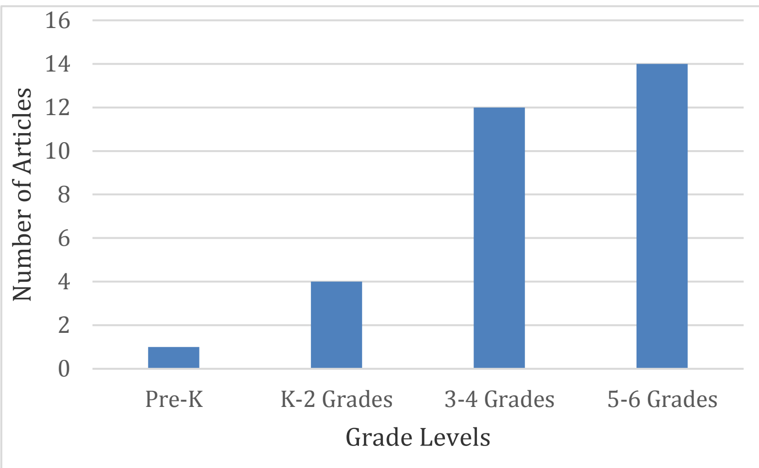

Figure 3. Number of Articles Targeted Toward Various Grade Ranges

'Activities that Work' as a Source of PCK for Teaching NOS

According to Magnusson et al.'s model (1999), there are several types of knowledge that comprise teachers' PCK for teaching NOS (Table 3). The majority of our sample included explicit information that addressed one or more of these component knowledge bases in relation to NOS. That is, they included relevant information that could inform teachers' knowledge of learners (KoL) such as common misconceptions of NOS, knowledge of instructional strategies (KoI) such as explicit and reflective approaches to teaching NOS, knowledge of curriculum (KoC) such as information about standards for teaching NOS and curricular materials, or knowledge of assessment (KoA) such as specific assessment tools for evaluating students' ideas about NOS.

Table 3. Number of articles that has potential information for each component of PCK for NOS.

Components of PCK for NOS	Sub-Components	Number of Articles		Total
		Only	Both	
Knowledge of Curriculum	Mandated goals and objectives	12	9	21 (87.5%)
	Specific curricular materials and programs	0		
Knowledge of Learners	Knowledge and beliefs about prerequisite knowledge	0	0	7 (29.2%)
	Knowledge of students difficulty	7		
Knowledge of Assessment	Knowledge of what concepts important to assess and strategies and techniques to assess them	8	1	9 (37.5%)
	Knowledge of how to interpret the results	0		
Knowledge of Instructional Strategies	Integrated Strategies	13	0	24 (100%)
	Non- Integrated Strategies	11		

Knowledge of Curriculum

Teachers' knowledge of curriculum consists of understanding mandated goals and objectives, as well as awareness of specific curricular materials and programs related to the subject matter they teach (Magnusson et al., 1999). It also includes knowledge about what students have learned in previous years and what they will learn in future years. As mentioned in above, 21 (87.5%) of the articles included information relevant to teachers' knowledge of curriculum; however, while 12 articles stated the mandated goals and objectives related to NOS, nine provided relevant examples of curricular programs or supplementary resources for teaching NOS. For example, one group of authors recommended the Mystery Boxes curriculum materials from the Science Curriculum Improvement Study (SCIS) (Knott & Their, 1993) as a means to emphasize NOS. Thus, Figure 6 should be interpreted with caution.

Knowledge of Learners

This component of PCK includes teachers' knowledge and beliefs about the prerequisite knowledge required for students to learn specific subject matter, as well as knowledge of areas of student difficulty (Magnusson et al. 1999). Our analysis revealed that seven out of 24 of the articles provided information about students' preconceptions and difficulties had about aspects of NOS. Students' misconceptions about NOS were often generally described and cited from research, however, rather than being drawn from the elicitation of student ideas during the activities described. Only two of the seven articles provided examples of student misconceptions elicited by assessments administered during the lesson. This reflects an overall lack of focus on assessment within the pool of articles we analyzed.

Knowledge of Assessment

Knowledge of assessment includes teachers' knowledge of what to assess, as well as how to assess it (Magnusson, et al. 1999). In other words, a teachers' knowledge of assessment reflects knowledge of what skills or concepts are important to assess, knowledge of strategies and techniques to assess, and how to interpret the results of assessments. Within this, assessment can be considered as consisting of both formative (embedded in instruction to provide feedback that supports teaching and learning) and summative assessments (administered following instruction to evaluate teaching and learning).

We examined each of the articles to identify relevant information that could inform elementary teachers' knowledge of assessment of NOS, and found that only nine of the articles (37.5%) explicitly identified strategies for assessing student learning of NOS. Furthermore, none of the articles we examined explicitly addressed how these assessments could be used to inform teachers' subsequent instruction or provided explicit criteria by which students' responses could be evaluated. One unique exception (Sickel, Lee & Pareja, 2010) provided an example formative assessment probe and discussed what types of student responses would indicate mastery level of understanding in regard to the empirical basis of science.

Knowledge of Instructional Strategies

Teachers' knowledge of instructional strategies is twofold; one dimension relates to knowledge of subject-specific strategies which consist of more general approaches for teaching the subject matter knowledge, and another dimension relates to the knowledge of topic-specific strategies which include both representations and activities to help enhance their ideas about specific concepts or ideas (Magnusson et al., 1999).

Within this framework, we identified articles that emphasized subject-specific strategies for NOS including inquiry-based instruction, and more general pedagogical strategies such as using children's literature. In terms of topic-specific strategies for teaching NOS, research describes activities as being either 'integrated'--that is, embedded in the teaching of science content—or 'non-integrated'—being taught as a stand-alone topic—though both have been shown to support student learning of NOS (Khishfe & Lederman, 2006). We found13 of 24 articles used integrated strategies whereas 11 of 24 used non-integrated activities for teaching NOS. Content embedded strategies require teachers to have deep understanding of content knowledge to be able to effectively integrate aspects of NOS into instruction. These kinds of activities can help illustrate to elementary teachers that NOS is not separate from their other science instruction; however, non-integrated activities may be a useful scaffold for elementary teachers who have weaker science content knowledge.

DISCUSSION

Although our content analysis has limitations, in that articles published in Science and Children are not necessarily a full account of what is occurring in classrooms more broadly, the results do provide a useful starting point for considering the research-practice gap in regard to NOS. We recognize that authors face space limitations, and that they are bound by recommended guidelines from editors, as well as feedback by reviewers. To that end, we hope to inform these diverse audiences (authors, reviewers, and editors) so that broader consideration might be given to the kinds of information that is needed in order to enhance the current status of professional literature in this area.

The current pool of articles in Science and Children provides a diverse array of 'activities that work' to teach NOS to elementary students. For example, there are multiple articles for each of the aspects of NOS we examined, providing options for teachers searching for information about specific aspects of NOS. To a lesser degree, there are articles provided for a variety of grade levels, though a greater number for upper elementary grades. An elementary teacher looking for an 'activity that works' to teach NOS would likely be able to find relevant examples within the journal.

However, we note several important limitations of the articles currently available to teachers. While the articles provide many example activities to teach ideas such as science is a human endeavor or science is based on inference, there are fewer examples of teaching about other aspects of NOS such as scientific theory and law and that science is socially and culturally embedded. The lack of emphasis on some aspects of NOS versus others might reflect the belief that these might not be easily integrated into the elementary curriculum or concerns about the developmental appropriateness of introducing specific ideas. Nonetheless, recent research suggests that even K-2 students, with appropriate and explicit attention to NOS, can develop their understanding (Quigley, Pogsanon, & Akerson, 2011). Regardless of the reasons, what becomes evident is that there is not an equivalent pool of 'activities that work' available to assist teachers in teaching each of the aspects of NOS outlined in reform documents, nor is there an even representation of NOS instruction at various grade spans. Thus, we believe the current practitioner literature could be enhanced by additional examples of NOS teaching and learning in primary grades, and especially for ideas about NOS currently underemphasized such as the use of creativity in science, the role of theory, and how science both influences and is influenced by culture.

Just as Jagger and Yore (2012) found that many articles in practitioner journals provided recommendations that were not anchored or justified with high quality evidence, we similarly found that only about half of the articles we analyzed reflected current research findings in terms of emphasizing the need for an explicit emphasis on NOS and outlining how that might be accomplished in the context of the activities described. Thus, perhaps unintentionally, some of the articles in Science and Children may contribute further to the research-practice gap with regard to teaching NOS noted by Lederman (2007). As Jagger and Yore (2012) emphasize, professional literature is shaped by a series of 'gatekeepers' including editors and reviewers; we note that the guidelines provided to authors of the articles we analyzed may have dissuaded the use of research evidence by cautioning authors to avoid becoming ''bogged down with references to others' research'' (NSTA, n.d., p. 3). Yet, we noted a high number of authors are researchers and/or teacher educators who, arguably, have familiarity with the body of research related to NOS and a keen awareness of the research-practice gap. In this regard, editors and reviewers can play a key role in providing feedback to authors that requests appropriate evidence for the efficacy of the activities described in articles and a description of how the activities draw on the research base. Along these lines, we note that NSTA has recently revised its guidelines for authors to encourage them to “support for claims made in the manuscript, including research citations and personal anecdotal evidence” (NSTA, n.d.).

Yet, the research-practice gap could potentially be reinforced if teachers fail to view the activities that are introduced by academics as recommendations from credible peers. We found the numbers of articles written by science teachers was low compared to the number of articles written by teacher educators and science education professors. Though many of the latter were once teachers themselves, prior to entering academia, there can nonetheless be a tendency for practitioners to view faculty as far-removed from the K12 setting. In such cases, it becomes even more critical that authors provide evidence that the activities ‘work’ with real students in real classrooms. Such evidence can come from sharing example assessments and student outcomes, yet we found in our analysis that very few articles provided information related to assessment of NOS.

Moreover, as we examined articles in relation to the various components of PCK, our analysis revealed that there were fewer inclusions of information that could help teachers build their knowledge of learners and knowledge of assessment for NOS, than for other components of PCK such as knowledge of instructional strategies. Teachers’ lack of knowledge for assessing NOS can prevent them from identifying their students’ misconceptions related to NOS, evaluating the impacts of their instruction on students’ ideas about NOS, and can limit their effectiveness in using assessment data to inform subsequent instruction (Hanuscin& Hian,2009; Hanuscin, Lee, & Akerson, 2010). Thus, articles that provide sample assessments, discuss student responses to those assessments, and guide teachers in using assessment data to guide their NOS instruction could go a long way toward addressing this issue.

Seeking out ‘activities that work’ is a common way that teachers attempt to improve their practice (Appleton, 2006). With the large membership in the organization and wide readership of NSTA journals, there is a potential for the practitioner literature to be a rich source of these activities. Further investigation of the status of professional literature in this area, as well as inquiry into how elementary teachers utilize professional literature to support their teaching of NOS is warranted.

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