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A Correlation of Teacher Understanding of NOS With Student Understanding

David G. Kent

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

A Correlation of Teacher Understanding of NOS With Student Understanding

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This is a study of how a teacher's understanding of the nature of science (NOS) correlates to student understanding of the nature of science. Participants are in semester long seventh grade science classes in a suburban school district. Seven strands of the nature of science were identified in the literature. Four strands were analyzed in this study.

Teachers were ranked according to their understanding of the nature of science and compared to their corresponding students' average gain. There was no definitive pattern between the teacher's and corresponding students' gain. When broken down by strand, there still was no definitive pattern between teacher's rank and their students' average gain. Teaching experience varied and provided significant differences between experience groups.

Two student ethnic groups produced significant negative overall gains. Only two student ethnic groups showed positive overall gains; however, they were insignificant. Students who reported to enjoy science showed a higher understanding of NOS than those who reported to not enjoy science.

Keywords: nature of science, student gains

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Introduction

This study was designed to examine the correlation between teacher understanding of the nature of science (NOS) with seventh grade science students' understanding. NOS is defined as thinking processes scientists use to solve problems. This study used a modified pre-post survey designed for assessing student understanding of NOS with a reliability of 0.79. In science education research there are few research instruments that adequately check for student understanding of NOS with validity cited as the biggest obstacle for development of student instruments (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Norm Lederman, a nationally known NOS researcher, suggested that not all components or strands of NOS need to be statistically validated at the same time. For this study researchers decided to assess NOS strands separately to develop an instrument for age appropriateness and to adequately develop multiple statements to maintain reliability and validity. Lederman stated a minimum of 8 questions per strand are required to ensure the validity of an instrument (N. Lederman, personal communication, June 2, 2009). The pre-post student survey for this study was modified from a previously developed instrument by Brad Talbert (2007), a Brigham Young University graduate student. This study extends Talbert's research by examining the correlation of teacher understanding of NOS and student understanding.

Research Question

How does teacher understanding of the nature of science (NOS) correlate with a seventh grade science student understanding of NOS?

Rationale

The aim of this study was to determine whether teachers who exhibit a high understanding of NOS effectively transfer this understanding to their students. Through a pre-post survey I expect to find a positive direct correlation between teacher knowledge of NOS and seventh grade science student understanding. Determining the correlation will provide evidence to suggest changes in science teacher education preparation, professional development programs, and teaching practices. I also anticipate that the findings from this study will emphasize the need for extended NOS learning in science teacher education preparation and in-service teacher professional development programs.

As a science educator with 5 years of experience, I became interested in NOS when I found that most of my students were expecting to learn simple scientific facts. My students expressed the misconception that science is complete and unchangeable, rather than tentative. When doing labs and other activities, students seemed to look for the “right” answer instead of observing real-time results that determine the outcomes of a study. From a professional standpoint, examining students with this misconception was a guiding factor behind conducting this study.

Definition of NOS

Science education researchers have not agreed upon a single, complete definition of NOS. Abd-El-Khalick, Bell and Lederman (1998) suggest the persistence of a lack of consensus of NOS lies in differences among philosophers, historians, and teachers of science as well as scientists. Abd-El-Khalick and Lederman (2000) also argue “conceptions of NOS have changed with developments in various scientific disciplines” (p. 666). Alters (1997) argues that all stakeholders may not need to be involved to create a definition for NOS. As a result, I chose to use the definition from McComas, Clough, and Almazroa (1998)

> The nature of science is a fertile hybrid arena which blends aspects of various social studies of science including the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group, and how society itself directs and reacts to scientific endeavors (p. 4).

I further studied specifics of NOS to examine teacher/student understanding more closely through literary research. I found that Lederman and Lederman (2004) divide NOS into the seven strands listed below. Based on Lederman's suggestion, I chose four of these strands (3, 4, 5, and 7) to analyze for this study:

1. Science has a crucial distinction between observation and inference
2. Science has a distinction between scientific laws and theories
3. Science is based on and/or derived from observations of the natural world
4. Science involves human imagination and creativity
5. Science is at least partially subjective
6. Science is socially and culturally embedded
7. Science knowledge is subject to change

Literature Review

Teaching NOS to students is not a new curricula concept in science education. Researchers and organizations have supported the idea that students in elementary and secondary schools should understand NOS for several decades (National Research Council, 1996; American Association for the Advancement of Science, 1993). Even though researchers, scientists, philosophers, and educators do not agree upon a single standardized definition of NOS, all groups agree that teaching NOS should be a priority. Martin-Diaz (2006) states:

> Movements such as “Science for All” (Reid & Hodson, 1987), “Science, Technology and Society (STS)” (Aikenhead, 1994, 2002; Bybee, 1985; Ziman, 1984), “Scientific Literacy” (Abd-el-Khalick, Bell, & Lederman, 1998; Hurd, 1997; Kolstoe, 2000; Marco, 2000) and “Public Understanding of Science” (Cross & Price, 1999; Jenkins, 1999; Tytler, Duggam, & Gott, 2001) have championed the need for students to familiarize themselves with what is meant by science, how it is undertaken, and how it evolves over time, so they can understand the meaning of scientific theories, and above all, so they assign an appropriate role for science in its relationship with technology and society and can distinguish between social situations in which scientific evidence exists and social situations in which there is no such evidence and ideological considerations are to the fore. It could even be considered essential to their participation in society as critical citizens capable of discussing and deciding upon issues in which science and technology have an important bearing (pgs. 1161-1162).

It is important for students to learn NOS to distinguish between scientific and non-scientific concepts (Scharmann & Smith, 2001). Bell and Lederman (2003) argue that “less emphasis should be placed on teaching isolated science facts and concepts and more emphasis placed on broad, overarching themes, including scientific inquiry and the nature of science” (p. 353). Further, lecturing students about NOS out of context of conducting scientific investigations may lead to a misunderstanding that science is a body of knowledge that is complete (Palmquist & Finley, 1997). Khishfe and Lederman (2006) state NOS should be “explicitly addressed and should be planned for instead of being anticipated as a side effect or secondary product" (p. 396). This explanation does not necessarily lead to didactic instruction but rather a practice of reflection and discussion (Khishfe & Lederman, 2007).

In addition, Niaz (2001) argues heuristic and empirical principles should be measured for understanding NOS. According to the American Association for the Advancement of Science (AAAS) (1993) in *Benchmarks for Science Literacy,* teaching students to simply conduct scientific experiments is not sufficient for understanding the thinking processes and nature of science. The National Science Education Standards suggest that high levels of scientific literacy include understanding of NOS through an empirical modality (NRC, 1996).

Lederman and Lederman (2004) claim that both teachers and students are lacking sufficient understanding of NOS explaining that science teachers need to have a deep understanding of NOS for students to have an understanding of the nature of science. Additionally, what science teachers choose or don't choose to teach about NOS creates their students' future views of science (Palmquist & Finley, 1997). Smith and Scharmann (1999) believe "the most important reason students should understand the nature of science is that this understanding is crucial to responsible decision making and effective local and global citizenship" (p. 495). Bentley and Garrison (1991) contend that science teachers have a bias based on their knowledge, or lack of knowledge, of NOS that leads to teaching a "hidden curriculum." Hidden curriculum is any curriculum that is put in or omitted from the content based on teachers' content knowledge. To help remove bias, science teacher education programs need NOS content and pedagogy to help students construct a deeper understanding of the sciences and the science community (Palmquist & Finley, 1997; Lederman & Flick, 2003; Bentley & Garrison, 1991). More recently, Schwartz, Lederman & Crawford (2004) report that techniques have been tried that improve the future educator's understanding of NOS in science teacher education preparation programs.

Many education researchers have linked teacher knowledge and instructional strategies directly to student achievement in several academic disciplines. Hill and Ball (2009) suggested that transfer of knowledge from a teacher to the student requires strong content knowledge and appropriate pedagogical skills. Ball, Thames, and Phelps (2008) reported teacher content knowledge is not enough if the teacher cannot disseminate the instruction to the students in a useful manner (Ball, Thames, & Phelps, 2008). Ball and Forzani (2009) argued, "teachers are key to student learning" (p. 497) Additionally, in 2007, math students in Japan participated in the trends of mathematics and science study (TIMSS). The results of TIMMS showed that teaching styles are positively correlated to mathematic assessment scores (House, 2009).

Ultimately, students learning about NOS will lead to greater scientific literacy for all students, a goal of many educators (AAAS, 1993; NRC, 1996). Smith and Scharmann (1999) state "few science educators are likely to disagree with this goal and most probably perceive…that they have an adequate personal understanding of the nature of science for their own instructional purposes" (p. 494). However, teachers and teacher candidates need sufficient training to help students understand NOS, as well as identify and clarify NOS misconceptions (Morrison & Lederman, 2003). Crowther, Lederman and Lederman (2005) argue that NOS should be implemented into science instruction daily just as any other topic. Lee and Chiappetta (2009), claim NOS is a base that should be used by teachers as a guide for disseminating information to their students.

However, when Lee and Chiappetta (2009) examined textbooks for the introduction of NOS, they found varying and often conflicting information. Although some topic commonalities existed, little detail to deepen understanding on some strands of NOS were presented (Lee & Chiapetta 2009). Niaz (2000) contends that textbooks should include strong emphasis of both heuristic and empirical principles of the NOS to help students because textbooks typically teach the hidden curriculum about NOS by implying a set "scientific method" approach to science (Bentley & Garrison, 1991). As textbooks are a primary curriculum tool, textbooks need to include appropriate information about NOS to help teachers overcome student misconceptions.

Methods

This methods section contains three subsections; a) research survey, b) research participants and setting, and c) data analysis. The survey section includes how the survey was administered, what the survey consists of, where it originated, and how survey responses were prepared for the final data analysis. In the research participants and setting section, the demographics and location of the participating teachers and students as well as the demographics of the participating school district are discussed. Details about data sorting and analysis are reported in the data analysis subsection.

Description of the Research Survey

The research survey used for this study was an extension of another graduate thesis conducted at Brigham Young University (Talbert, 2007). Talbert developed the Characteristics of Science Questionnaire (CSQ) with a reliability of 0.79. The CSQ was designed to examine student understanding of all seven strands of NOS. Talbert did not attempt to examine a correlation between teacher and students. In addition, I added a question about student interest in science because I felt that could have an impact on the results of the students' responses.

This quantitative study utilized a survey designed for understanding of NOS of seventh grade science teachers and their students modified from the CSQ. Teachers and students took the modified CSQ at the beginning and the completion of their regular school science course. The modified CSQ was designed with statements that measured understanding of four strands of NOS.

The modified CSQ consisted of 36 statements describing four selected strands of NOS (see Appendix A). The four strands chosen and analyzed were: a) observation of the natural world, b) creativity c) subjectivity (a scientist's preconceptions and biases influence collection and interpretation), and d) tentativeness (scientific knowledge changes as new information is gathered). Four answer choices for each statement followed the Rausch Model: Definitely True, Probably True, Probably False, and Definitely False.

The teacher and student responses were collected at each school electronically via SurveyMonkey (www.surveymonkey.com), an online survey collection service. Each school had a computer lab accessible to complete the modified CSQ and both school district and university IRB approval were obtained. Students and teachers were assigned a six digit numeric code to help maintain confidentiality and track an individual's answers. Responses were deleted from the final data set based on the following errors. First, I removed any response that had an incorrectly entered numeric code. Second, any code that was not exactly six characters or had letters and/or symbols were eliminated to avoid any assumptions or bias. Third, responses were also removed from the data set if the student did not complete both the pre- and post- survey or failed to answer more than 2 of the 36 questions. Finally, other survey responses were expunged based on a minimum time (2 minutes) it took to complete the survey. A beta test was set up with a control teacher and corresponding students to determine the baseline for this time limit. We also took into account a student's reading level, ELL level, and the general nature of a student to earnestly complete surveys for research for this 2 minute minimum.

Research Participants and Setting

I asked various questions to analyze the survey by demographics. Teacher profile questions included the number of years the teacher has been a practicing teacher, ethnicity, and gender. Student profile questions included ethnicity and gender as potential factors in NOS understanding. I also asked students to select their level of science interest as definitely true to definitely false to further analyze data.

Participants for this study were Utah seventh grade science teachers and students. The school district chosen for this study taught seventh grade science in one semester instead of a year. This district wide study had six Junior High Schools with one to three seventh grade science teachers per school. Twelve teachers were solicited and 10 participated in this study. Pseudonyms were provided to maintain confidentiality. All 10 teachers were white (non-hispanic) and their teaching experience varied from 1 year to more than 15 years teaching. Four teachers have taught more than 15 years, three from 10-15 years, three less than 6 years. Seven teachers were male (Blaine, Tom, Don, Frank, Alexander, Chris, and Pat) and three female (Samantha, Julene, Daphne).

Table 1

Teacher Demographics

Ethnicity	Experience	Gender
100% White (non-Hispanic)	30% less than 6 years	70% Male
	30% 10 to 15 years	30% Female
	40% More than 15 years	

A total of 620 students attempted the survey. After answers were eliminated based on the 2 minute minimum, a correct numeric code, and completion of both the pre- and post- survey, a total of 450 students were analyzed. Of these 450 students, 86.2% were white (non-hispanic), 6.7% Hispanic, 2% Native American, 1.8% African American, 0.9% Pacific Islander, and 2.4% other. The student respondents consisted of 54.4% female and 45.6% male.

Table 2

Student Demographics of Respondents

Ethnicity	Gender
8 (1.8%) African American	45.6% Male
30 (6.7%) Hispanic	54.4% Female
9 (2%) Native American	
11 (2.4%) Other	
4 (0.9%) Pacific Islander	
388 (86.2%) White (non-Hispanic)	

Within the school district studied, the student ethnic composition was similar to that reported for the student participants. Of the 28,282 district student population, 87.7% are white (non-hispanic), 9.22% Hispanic, 0.81% Native American, 1.13% African American, 0.93% Pacific Islander, and 0.64% other. Asian students were not reported in the seventh grade science classes, but the district reports 2.48%. There was a difference in gender at the district level with 51.7% male and 48.3% female. Based on the district composition, I determined that the student participants were a representative sample of the district student population.

Data Analysis

Data from the surveys were analyzed using ANOVA with a Tukey-Kramer Post Hoc Test for pair-wise comparisons. Analyses were run on teacher versus class, teacher versus teacher experience, teacher versus teacher gender and ethnicity, teacher versus student gender and ethnicity, and student interest in science. Teacher understanding of NOS was measured against the average student gain of NOS understanding by class for each teacher. Each of the four strands of NOS measured in this study was also analyzed by teacher and student ethnicity.

Findings

Teacher Understanding vs. Class Understanding

Overall gains in understanding.

Teachers were ranked from highest understanding to lowest understanding as established by the same survey the students took (see Table 3). A score of zero was set as the best possible score. The teachers were then compared with the average gain of their students' understanding of NOS. Students were grouped by teachers and the class was used as the unit of analysis. Only 2 of the 10 groups had a positive average gain, while the other 8 groups had a negative average gain over the course of the semester. Three groups of students had a statistically significant negative gain. However, only one group produced a statistically significant positive gain.

There was no pattern of gain based on teacher understanding of NOS. Some of the teachers with high understanding of NOS produced positive student gains, but others with high understanding had negative student gains. Likewise, teachers with a lower understanding of NOS produced higher student gains while others produced lower student gains. The 2 teachers that produced the positive average gains were ranked in the top 3 of teacher understanding. Students that produced the third highest gain had a teacher that ranked number 9 on teacher understanding. However, only 1 of the 3 teachers with the lowest average student gains were ranked in the bottom 3.

Table 3

Student Understanding of NOS by teacher rank

Teacher Understanding Rank (High to Low)	Teacher Score (Max score = 0)	Class Overall Gain (average)	p-value
Samantha	16	1.488	0.233
Blaine	19	-1.7759	0.1031
Julene	22	4.3201	0.0202
Tom	23	-1.0464	0.3204
Daphne	24	-7.2130	0.0093
Don	25	-2.7380	0.014
Frank	27	-1.4987	0.1997
Alexander	30	-0.6539	0.6099
Chris	30	-0.166	0.8851
Pat	32	-3.0343	0.009

Gain in student understanding by strand.

When separated by strand, teachers were not ranked in the same position as the overall ranking (see Tables 4, 5, 6, & 7). Each teacher had their own strengths and weaknesses between the different strands. However, the groups still showed varying results between each strand. Teachers that ranked high in some strands had students with the lowest gains while teachers that ranked lower had students with the highest gains in the NOS strands.

In Table 4, the observation strand was analyzed by teacher rank and student performance. Julene's students had significant positive gains. Frank and Pat's students had significant negative gains for the observation strand. The 2 teachers with the highest average student gain for this strand ranked number 1 and 2 for understanding. The teacher with the lowest average student gain ranked number 3.

Table 4

Student Understanding of the observation strand of NOS by teacher

Teacher Understanding Rank (High to Low)	Teacher Score	Student Average Gain	p-value
Samantha	1	0.2525	0.6408
Julene	4	1.8521	0.0229
Blaine	6	-0.4173	0.3736
Frank	6	-1.0652	0.0416
Tom	7	-0.3041	0.5082
Daphne	7	-2.2896	0.0525
Don	7	-0.6855	0.143
Alexander	7	-0.4898	0.3863
Chris	8	0.07089	0.8881
Pat	8	-1.0247	0.0392

In Table 5, the creativity strand was analyzed by teacher rank and student performance. Don was the only teacher with significant student gains for the creativity strand and they were negative. The teacher with the highest average student gain for this strand ranked number 6 for understanding. The teacher with the lowest average student gain also ranked number 6.

Table 5

Student Understanding of the creativity strand of NOS by teacher

Teacher Understanding Rank (High to Low)	Teacher Score	Student Average Gain	p-value
Blaine	2	-0.9088	0.0721
Samantha	3	0.6888	0.2319
Tom	4	-0.1596	0.7404
Frank	4	0.1069	0.8408
Alexander	4	-0.3431	0.5633
Julene	5	0.7668	0.35
Don	5	-1.7524	0.0011
Pat	5	-0.7713	0.1316
Daphne	6	-1.3678	0.259
Chris	7	-0.2961	0.5773

In Table 6, the subjectivity strand was analyzed by teacher rank and student performance. This strand had the lowest scores for teacher understanding with the most negative gains. Don was again the only teacher that produced significant student gains for the subjectivity strand and they were negative also. The teacher that produced the highest average student gains for this strand ranked number 3 for understanding. The teacher with the lowest average student gain also ranked number 3.

Table 6

Student Understanding of the subjectivity strand of NOS by teacher

Teacher Understanding Rank (High to Low)	Teacher Score	Student Average Gain	p-value
Tom	6	-0.7024	0.1507
Don	7	-1.0007	0.0457
Samantha	8	-0.2897	0.6093
Julene	8	-0.02497	0.9754
Daphne	8	-2.2175	0.071
Blaine	10	-0.4115	0.4021
Frank	11	-0.7037	0.1872
Chris	12	-0.8094	0.1136
Pat	13	-0.9563	0.0634
Alexander	14	-0.3195	0.5878

In Table 7, the tentativeness strand was analyzed by teacher rank and student performance. This strand had the best scores for teachers with the most positive gains. However, none of the teachers had students with significant gains for tentativeness. The teacher with the highest average student gain for this strand ranked number 5 for understanding. The teacher with the lowest average student gain ranked number 2.

Table 7

Student Understanding of the tentative strand of NOS by teacher

Teacher Understanding Rank (High to Low)	Teacher Score	Student Average Gain	p-value
Blaine	1	0.1525	0.7653
Daphne	2	-1.0309	0.3772
Chris	3	1.0157	0.0818
Samantha	4	0.8687	0.132
Julene	5	1.4496	0.1069
Alexander	5	0.6391	0.3209
Tom	6	0.3098	0.5671
Don	6	0.1101	0.8315
Frank	6	0.02288	0.9667
Pat	6	1.0157	0.0818

Teacher Demographics

There were no significant differences when teacher gender was analyzed. Since all of the participating teachers were white (non-Hispanic), there were no tests ran to analyze ethnicities. However, differences among teacher experience produced significance. Teaching experience was divided into 3 groups: a) less than 6 years, b) 10 to 15 years, and c) more than 15 years. Teachers that taught between 10 and 15 years had significantly better results than the other 2 groups. There was no significant difference between the groups less than 6 years and more than 15 years (see Table 8).

Table 8

Teacher Experience Effects on Student Understanding of NOS Gains

Teacher Experience	Difference of Average Gain	P-value
< 6 vs. 10-15 years	-2.3318	0.0068
<6 vs. More than 15 years	0.1789	0.8381
10-15 vs. More than 15 years	2.5107	0.0156

Student Gender and Ethnicity

Student understanding was analyzed by gender and no significant difference was found. Additionally, student ethnicity was analyzed and significant differences were found (see Table 9). The significant student gains were negative. African Americans and the "other" ethnic groups showed significant negative gains. Hispanics and Native Americans also showed negative gains, but were not found significant. White (non-Hispanics) and Pacific Islanders were the only 2 groups with positive gains, but neither of those gains was found significant even though Pacific Islanders had the highest overall gain.

Gains were also analyzed by strand and ethnic group. Subjectivity showed significant negative gains among African Americans and white (non-Hispanics). All teachers showed lower understanding of subjectivity. No other strand was found to have significant gains among the ethnic groups (see Table 9).

Table 9

Student Gains in Understanding of NOS by Ethnicity

Ethnicity	Average Gain (p-value)	Observation (p-value)	Creativity (p-value)	Subjectivity (p-value)	Tentativeness (p-value)
White (non-Hispanic)	0.1137 (0.7711)	0.03134 (0.8549)	0.2232 (0.2162)	-0.4007 (0.0258)	0.2609 (0.1789)
Hispanic	-1.4954 (0.1986)	-0.4927 (0.3340)	-0.2631 (0.6240)	-0.5107 (0.3385)	-0.2793 (0.5435)
Other	-4.6201 (0.0118)	-1.5154 (0.0595)	-1.1304 (0.1807)	-1.5666 (0.0625)	-0.3345 (0.6335)
Native American	-2.3612 (0.2515)	-0.9329 (0.3019)	-1.7618 (0.0642)	-0.3315 (0.7252)	0.8691 (0.2692)
African American	-4.4463 (0.0384)	-0.7631 (0.4165)	-0.7274 (0.4653)	-2.4700 (0.0122)	-0.3850 (0.6396)
Pacific Islander	5.4184 (0.7711)	1.2123 (0.3632)	1.2376 (0.3773)	0.8180 (0.5571)	2.1224 (0.0665)

Student Interest in Science

Students were asked whether they enjoyed science to determine if interest was a variable. The answer choices for this statement were written in the same format as the other survey statements. Table 10 showed the amount of students who selected false increased from pre- to post- surveys by 6.5%. However, only 1.1% changed their selection for those that definitely enjoyed science.

Table 10

Comparison of Interest in Science from Pre- to Post-Survey

	Definitely False	Probably False	Probably True	Definitely True
Pre-Survey	9.58%	14.03%	35.41%	40.98%
Post-Survey	16.70%	13.36%	30.07%	39.87%

Students that selected "definitely true" on the post-survey posted a significantly lower (note: lower is better) average score than students that selected "probably false" and "definitely false." "Probably true" was not significantly different than probably false or definitely false. Likewise, probably false and definitely false were not significantly different from each other (see Table 11). Average gains from pre- to post-survey were also analyzed by student interest in science using a Tukey-Kramer post hoc test. No significant differences were found.

Table 11

Comparison of Interest in Science Post-Survey Scores

	Difference of Average	P-value
Definitely False vs. Definitely True	2.4332	0.0221
Definitely False vs. Probably False	-1.0682	0.7451
Definitely False vs. Probably True	0.9203	0.7239
Probably False vs. Probably True	1.9885	0.1573
Definitely True vs. Probably False	-3.5014	0.0009
Definitely True vs. Probably True	-1.5129	0.1363

I further analyzed students that selected definitely true for the interest in science question on the post-survey. One teacher was eliminated from the data set having no students who selected definitely true. There was a significant difference between teacher gender and overall student gains. Teaching experience did not produce significance in the overall student gains among the definitely true student interest group (see Table 12).

Table 12

Teacher Demographic Effects of Student Overall Gains for Students that Reported they Definitely Enjoyed Science

Label	Average Gain	P-Value
teacher gender	3.7162	0.0117
less 6 vs 10 to 15	-1.2279	0.3229
less 6 vs more 15	-0.4523	0.6523
10-15 vs more 15	0.7757	0.5449

I further analyzed the student interest in science data set by strands. In the observation strand, teacher gender showed a significant difference for student gains. Teaching experience also produced significant differences in student gain between groups in the observation strand. The only significant difference found was between the 1 to 6 year experience group and the 10 to 15 year group (see Table 13). African Americans also produced significant positive gains in the observation strand which is opposite of their gain when all students were included (see Table 14).

Table 13

Teacher Demographic Effects of Student Observation Gains for Students that Reported they Definitely Enjoyed Science

Label	Average Gain	P-Value
teacher gender	1.8871	0.0087
less 6 vs 10 to 15	-1.2192	0.0494
less 6 vs more 15	-0.3356	0.4915
10-15 vs more 15	0.8836	0.1617

Table 14

Student Ethnicity Effects of Student Observation Gains for Students that Reported they Definitely Enjoyed Science

Student Ethnicity	Average Gain	P-Value
African American	6.7251	0.0157
Hispanic	-0.3568	0.6273
Native American	-2.8145	0.3079
Other	-2.4517	0.0784
Pacific Islander	1.4299	0.4637
White (non-hispanic)	0.08172	0.7319

In the creativity strand, Samantha and Frank showed significant positive student gains (see Table 15). Table 16 shows that for the creativity strand, white (non-Hispanic) students had significant positive gains. No other significance was found.

Table 15

Teacher Effects of Student Creativity Gains for Students that Reported they Definitely Enjoyed Science

Teacher	Average Gain	P-Value
Samantha	2.4187	0.0148
Julene	0.9143	0.4917
Frank	1.9153	0.0498
Alexander	0.3886	0.7139
Don	-0.3675	0.6706
Pat	0.6871	0.447
Tom	1.1092	0.1937
Blaine	0.64	0.4965
Chris	1.9014	0.0974

Table 16

Student Ethnicity Effects of Student Creativity Gains for Students that Reported they Definitely Enjoyed Science

Student Ethnicity	Average Gain	P-Value
African American	1.6069	0.5485
Hispanic	-0.3561	0.6158
Native American	3.4233	0.197
Other	-1.5741	0.2415
Pacific Islander	2.4205	0.1964
White (non-hispanic)	0.8842	0.0002

No significant difference was found in the subjectivity and tentativeness strands. When the students that definitely enjoyed science were analyzed, the subjectivity strand showed higher student gains than when everyone was included and tentativeness showed lower student gains.

Discussion

The findings from this study provide interesting insights for science education researchers, pre-service teacher developers, and teacher professional developers regarding the understanding of NOS. I discuss specifics regarding the implications of this study in to general areas; a) pattern between teacher content knowledge and student understanding and b) student demographics and NOS understanding. For future research, implications of this study are discussed at the end of this section.

Pattern Between Teacher Content Knowledge and Student Understanding

In this study, I was looking for a correlation between teacher understanding of NOS and student understanding of NOS. However, no pattern of teacher content knowledge of NOS and student understanding of NOS was found. All of the teachers that had high negative gains were scattered among the teacher rankings. However, the teachers with highest negative student gains were not the teachers with the three lowest scores for understanding of NOS. Likewise, the teachers with positive student gains were also scattered from top to bottom in the rankings. Therefore, no direct correlation between teacher knowledge and student understanding existed.

I reasoned that sound pedagogical skills could be a factor in student understanding. Without effective pedagogical skills, the teacher's content knowledge could not be transferred to the students (Hill & Ball, 2009). Teachers may not have the tools to transfer their knowledge to their students; or teachers have not improved their teaching practices over the years.

The data show that teacher rank by content knowledge of NOS did not necessarily indicate teachers transferred this knowledge to their students. When analyzed by strand, even teachers that ranked the highest in a single strand did not show highest student gains. Daphne ranked second in tentativeness but her students showed the only negative gain in the tentativeness strand. Don ranked second in the subjectivity strand and his students showed a significant negative gain for the subjectivity strand. Julene ranked 5th and 6th in tentativeness and creativity, respectively, and her students showed the highest gains for tentativeness and creativity strands. While the teacher scores were not bad for any of the strands, getting the message across to the students was not found to be the case in this study. Therefore, I conclude that higher teacher understanding of NOS does not directly correlate to the students understanding of NOS.

Subjectivity produced the lowest student gains. All of the gains were negative for this particular strand. Each teacher also had lower understanding of subjectivity than the other three strands. This may be an example of teachers creating misconceptions of science (Palmquist & Finley, 1997). Bentley and Garrison (1991) suggest that teachers may be exhibiting the outdated positivist approach, that scientific principles can be induced with certainty, to science where theory and personal thought do not mix. Being subjective in science is a relatively recent idea. Teachers lacking subjectivity knowledge of NOS is a reason science education researchers suggest NOS content changes in pre-professional teacher education and professional development programs (Palmquist & Finley, 1997; Lederman & Flick, 2003; Bentley & Garrison, 1991). By not having stronger understanding of the subjectivity strand, teachers are not able to transfer this knowledge to the students. As a result, this would be considered teaching the misconception of science as positivist, a hidden curriculum (Bentley & Garrison, 1991)

Teacher Demographics and NOS Understanding

Teacher gender showed no significant difference when all students were included in the data set for this study. However, it should be noted that two of the three female teachers showed the highest understanding of NOS. No test for teacher ethnicity was performed in this study because all teachers were white (non-Hispanic).

However, teaching experience did produce significant results. The teachers that are early and late in their careers had students that produced lower gains in understanding of NOS. Those in the middle (10-15 years) showed significantly better gains than the other two groups. The discrepancy between the experience of teachers could be explained by different variables. During the first 6 years, teachers may be trying to figure out the practice and art of teaching in their own classroom. On the other end of the experience spectrum, teachers that have taught for more than 15 years may unmotivated to change. Teachers in the more than 15 year group have taught for so long, a rigid routine may have developed. It is also a possibility that more experienced teachers have stopped participating in science professional development programs. Teachers with 10 to 15 years experience would be less likely to be unmotivated to change. Middle level experience teachers probably produce higher quality lesson plans to facilitate the transference of knowledge to the students.

Teaching experience is not always limited by the number of years a teacher has taught. Participating in research based professional development programs also counts as experience. Two of the teachers in this study participated in professional development programs that require participants to perform research. This increases their NOS content knowledge and the value of research in the classroom. Of the ten teachers, these two teachers were the only ones to have positive average gains with their students; one had significant gains.

Another variable that may have caused the negative student gains for some of the participating teachers was the practice of teaching NOS as a unit instead of integration through the entire course. Khishfe and Lederman (2006) suggest articulating NOS instruction throughout the entire course of study to improve student understanding. Several of the participating teachers mentioned at the beginning of the pre-survey to the researcher that their students should do well on the pre- and post-surveys as they had already taught NOS. If teachers did teach NOS as a unit instead of an ongoing process, students may have not retained NOS content a few months later.

Student Demographics and NOS Understanding

I analyzed students by gender, ethnicity, and interest in science. There was no significant difference regarding gender. The students that had significant negative gains were African Americans and the “other” categories. The teachers teaching NOS were from a homogenous culture that is predominantly white (non-Hispanic). As minorities, these two student groups may not have had their cultural learning needs met.

When I further analyzed the data by those who selected that they enjoyed science, two ethnic groups showed a decline in overall gains, but all other ethnicities had higher overall gains than when all students were included. This could be attributed to more effort put forth to understand NOS throughout the course of study. Or this may also be an indicator that teacher ethnicity may not have a strong influence on learning for students from differing ethnicities.

The reason for analyzing only those students that reported definitely enjoying science was to examine possible differences in student responses from students who selected that they did not enjoy science or were not sure. Those that enjoy science may have put forth more effort into learning NOS than the students that selected that they do not enjoy science. Every teacher showed higher overall gains than when all students were analyzed.

Students that enjoyed science had a higher understanding than those that did not. This could result from students that enjoy science putting forth more effort in their classrooms. Therefore, students who participate more understand NOS better than those that do not enjoy science and do not actively participate in their classroom. It should be noted that not all students that enjoyed science showed a higher understanding of NOS. Likewise, not all students who did not enjoy science received a score showing lower understanding of NOS at the end of the semester. However, there was not a significant difference found among the gains of understanding. Many students changed their interest in science over the semester long course. Not all students that switched their interest changed from enjoying science to not enjoying science. Most of the students that switched from enjoying science to not enjoying science came from the probably true category. Some of the students changed their selection from not enjoying science to enjoying science. A cause for this change of selection could be teacher specific, teaching style, or the student’s confidence in science.

Implications and further study

More information should be collected about the correlation of a student’s interest in science with their teacher’s understanding of NOS. In this study, I saw a change of many students' minds about their enjoyment of science over the course of the semester. I don't know if this was due to the teacher, the teaching style, or the students themselves. Additionally, a better understanding of how ethnicity impacts understanding of NOS could be studied further. I could not determine if certain ethnic groups' understandings are tied to the ethnicity of the teacher since all teachers in this study are of the same ethnicity.

Some teachers enter the profession after spending time in another field. This information was not solicited from the teachers for this study. Often, they come in with little pedagogical skills and training. If this variable impacts student understanding of NOS, then the professional development programs would be critical for these teachers' success.

A problem occurs when teachers cannot transfer their knowledge to their students. Science teacher preparation and professional development programs need to be developed with a stronger focus on all strands of NOS integrated with pedagogy. In this study, I found that teachers from all professional experiences benefit from continually attending NOS professional development.

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Appendix A

Survey Statements

1. Scientific knowledge is always based on the human senses.
2. Scientific research tries to create new knowledge by experimenting.
3. Scientists' personal views influence the way they collect and understand data.
4. Science does not change when we learn new information.
5. Science is based on old knowledge.
6. Scientists make judgments based on their experiments.
7. People who are not trained scientists can use scientific skills to evaluate what they see on TV.
8. Scientists review and evaluate experiments performed by other scientists.
9. Scientific ideas never change even after they find new information.
10. Science is always influenced by the opinions of the scientist.
11. Scientific research tries to create new knowledge based on conclusions from the human senses.
12. Scientists describe the results of their experiments with enough details so that others can judge the quality of the experiments.
13. Results of experiments are not infuenced by the scientist's experience or expectations.
14. Scientists question ideas currently thought to be correct to gain a more complete understanding.
15. Good conclusions reached by a scientist depend on the quality of the experiment.
16. Scientists prefer simple explanations for their experiments.
17. Scientists from different science subjects (biology, chemistry, physics, etc...) learn more

by working together.

18. Scientific knowledge always changes when new information is learned.
19. Scientists should question other scientists' experiments.
20. Science tries to create new knowledge by gathering information based on scientific questions.
21. Scientists plan better experiments by reading other scientists' experiments.
22. Science is not based on a scientist's opinions.
23. The results of one experiment can be used to establish scientific truth.
24. Scientists look for patterns in the data they collect from their experiments.
25. Scientists try to show that their ideas are wrong.
26. Scientists read other scientists' experiments.
27. Scientists should be open to new ideas.
28. Scientists do experiments on things they have seen many times.
29. Scientists try to create new knowledge by developing new questions.
30. Experiments tell scientists whether new technology is good or bad.
31. Scientists do not believe the results from just one experiment.
32. Results from an experiment are "scientific" if they are based on data.
33. Successful scientists are creative and imaginative.
34. Results of experiments are argued by different scientists.
35. Scientists try to show that a good idea cannot be proved wrong.
36. Scientists must explain their experiments well enough so others understand.
37. I enjoy science