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Science Pedagogy, Teacher Attitudes, and Student Success

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Abstract

Through a century-long process, there has been a resolute effort to shape science teaching in elementary classrooms. A close look at science teaching and student learning may provide a better understanding of what really happens in elementary classrooms. This study examines relationships between science teaching pedagogy, teachers' science teaching attitudes, and student learning outcomes 15 Oregon fifth-grade teachers. The resulting qualitative and quantitative data provides insights into the relationships between teacher practices and attitudes and student success.

Introduction

Since the Sputnik days of the late 1950s, a multitude of research studies have explored the need for changes in science education. During the past decades, reports, white papers, and studies repeatedly established American school children's lack of scientific understanding. In response, The National Research Council (1996) published National Science Education Standards (NSES) with the vision of a scientifically literate society with an understanding of significant science content and the ability to apply that knowledge to understanding happenings in everyday life. The NSES describe essential science content students need to know and the value of cooperation and collaboration in science. According to the NSES guidelines, the process of learning science concepts should involve a significant portion of time working with other students in science inquiry: experimenting, collecting and interpreting data, and discussing outcomes (Hurd, 2000; NRC, 1996; NSTA, 1991; Rutherford & Ahlgren, 1989).

The standards are clear about the value of inquiry pedagogy in teaching science, but teachers decide what actually happens in classrooms (AAAS, 1995). The attention of educational reform is now focused on quality teaching as much as on curriculum to improve education in areas in which quality science teaching is linked to both content knowledge and pedagogy proficiency. An increasing body of research strongly links low student test scores to poor teaching, some to the extreme that the single most influential factor, next to parental involvement, in student success is the teacher (de Souza-Barros & Elia, 1997). Implementing a standards-based science curriculum is difficult for many elementary teachers and is reflected in the amount of time teachers devote to science instruction. This is shown in a survey of kindergarten through fifth grade teachers conducted by Fulp (2002) in which teachers reported spending only 25 minutes each day in science instruction, compared to 114 minutes in reading and language arts, 53 minutes in math, and 23 minutes in social studies. Other studies find that the ability and desire to teach as the NSES suggest is related to several intrinsic factors including teacher attitudes regarding science and science instruction, limited content knowledge (which is related to desire to learn science), and pedagogical experience (Abell & Roth, 1992; Hewson, Kerby, & Cook, 1995; McDevitt, Heikkinen, Alcorn, Ambrosio, & Gardner, 1993).

The aim of the study is to analyze the relationships between elementary science teachers' pedagogical practices and attitudes and the success of their students in learning science.

Background

Student learning is affected by multiple factors. In the realm that schools control, teachers and instruction are the major influence on what, how, and how much students learn. Two important teacher factors, pedagogy and attitude, influence much of what happens in science instruction and the resulting student learning (Shrigley, 1983; Tobin, Tippins, & Gallard, 1994).

The Value of Inquiry Pedagogy and Student Learning in Science

Understanding the fundamental nature of science is embedded in inquiry-based learning, providing a better grasp of the concepts and processes of science. Inquiry in the elementary classroom combines a variety of skills and science processes. Students ask questions; make observations; plan and conduct experiments; gather and analyze data; use critical thinking; develop explanations, conclusions, and predictions; and communicate their findings to others (NRC, 1996).

The value of inquiry learning strategies has been noted in increased science achievement and cognitive development for students (Koballa, 1986; Krajcik, Marx, Blumenfeld, Soloway, & Fishman, 2000; Shymanski, Kyle, & Alport, 1983). A study comparing the effects of gender to inquiry-based teaching in the fourth grade found girls and boys both improved in science achievement when taught using inquiry (Dalton, Rawson, Tivnan, & Morocco, 1993). This is especially interesting when considering the lack of student learning in science described by the Trends in International Math and Science Study (TIMSS). TIMSS reports that in the 2003 tests, United States fourth graders were outperformed in science by fourth grade students from 8 of the 24 participating countries. United States eighth grade science students were outperformed by 32 of the 45 participating countries (National Center for Education Statistics, 2004). National Assessment of Educational Progress (NAEP) data establishes that American science students are not making progress towards catching up with science students in other countries, as NAEP science scores for fourth and eighth grade students show no improvement from 1996 to 2000 (National Center for Education Statistics, 2002).

Critically, how well students gain a conceptual understanding of science is related to how their teachers teach science (Kennedy, 1998). To be effective, science teachers need to possess the ability to represent important ideas and abstract concepts in a way that makes them understandable to students. The ability to make this connection is the root of effective teaching; effective teachers possess content knowledge and the pedagogy skills most effective to teach the subject matter (Dewey, 1939) and in student learning.

Scientific inquiry has a definite role in student success, but is there assurance that teachers are able to effectively implement inquiry learning pedagogy in their classroom?

Research finds that inquiry-based instruction requires teacher skill beyond the usual pedagogy. Teachers need to have an understanding of inquiry in order to effectively teach inquiry. Most teachers have not had opportunities to learn science in this manner or to conduct science inquiries themselves (Johnson, 2004).

Science Teaching Attitudes and Student Learning

The lack of skill and knowledge in science teaching is related to teachers' attitudes about science teaching (Shrigley, 1983). The word *attitude* describes outward and observable actions relating to beliefs. Attitudes are rooted in experience and affect what an individual will see, hear, think, and do. The outcome of attitudes is the tendency to react favorably or unfavorably to situations, persons, or events. Accordingly, teacher actions are shaped by their attitudes. Numerous studies agree on the positive correlation between science teaching attitudes and the ability to be an effective science teacher. Factors affecting teaching attitudes are found to include confidence about subject content, willingness to utilize curricular and pedagogical innovations, and a commitment to student learning (de Souza-Barros & Elia, 1997). Westerback & Long (1990) explain that teachers who are comfortable teaching science are more likely to devote more time to science teaching and will teach with more creativity. Over the years, many studies have reported that teachers who have positive attitudes about their teaching can have a significant impact on their students' achievement (Ashton, Webb, & Doda, 1983; Berman & McLaughlin, 1977; Guskey, 1980; Lasserre, 1989).

In contrast to previous research, however, TIMSS found that teachers with positive attitudes about the NSES, in actual practice, do not follow reform standards. Teachers rely on textbooks that cover a wide range of topics, emphasizing simple knowledge and routine procedures with little problem solving and critical thinking required of students. TIMSS concludes that teachers attempt to do what is expected of them but have insufficient time to teach the full range of content with the depth needed to meet the NSES. They select the quickest and easiest way to teach, which tends to be the pedagogy with which they are most familiar and use everyday (National Center for Education Statistics, 2004).

There is a critical combination of qualities that enable teachers to succeed in standards-based teaching. This study examines relationships between science teaching attitudes and science teaching pedagogy of fifth grade teachers and the science learning outcomes of their students. Prior research has not addressed this combination of teacher variables and student success. Specific research questions include the following:

- Is there a relationship between science teaching attitudes and science teaching pedagogy?
- Is there a relationship between pedagogy and student learning?
- Is there a relationship between science teaching attitudes and student learning?

Methodology

The practices and beliefs of elementary science teachers and their relationship to the success of students are complex. Instructional pedagogy utilized in classrooms, a survey of teacher attitudes, student test data in science content knowledge, and inquiry work samples are examined in an effort to gain an understanding of this complex interaction. This study was designed to utilize a variety of instruments, primarily focusing on quantitative measures. A pedagogy analysis instrument that focused on inquiry was employed, and teacher attitude was measured using a quantitative survey. Standards-based assessments already required for fifth grade students were selected for student inquiry and content knowledge data. Qualitative teacher data and anecdotal information were also collected.

Instruments and Data Collection

The Shrigley-Johnson Science Attitude Scale for Elementary Teachers (SAS), a self-reporting instrument, is used to measure science teaching attitudes. The SAS questionnaire consists of 25 questions about science interests and science teaching. Using a Likert scale, respondents select one answer for each statement: strongly agree (5), agree (4), not sure (3), disagree (2), or strongly disagree (1). Positive statements are scored with five points for "strongly agree" statements, four points for "agree," and so forth. In scoring negative responses, the weights are reversed with strongly agree (1), agree (2), etc. The total SAS score can vary from a low of 25, the most negative attitude, to a high of 125, the most positive attitude. A test-retest method reports the SAS to have a reliability coefficient of .92 (Shrigley & Johnson, 1974). The SAS was used by Damnianovic (1999) to evaluate the differences in attitudes of preservice and inservice teachers toward science learning and teaching in both traditional and inquiry-based settings. Damnianovic concluded that the SAS is a reliable instrument that can be used to assess teachers' attitudes about standards-based teaching practices in general and inquiry instruction in particular.

The Science Teacher Inquiry Rubric (STIR) (Beerer & Bodzin, 2004b) is used to quantify observations of inquiry-based science teaching. The STIR scores five features of science teaching pedagogy on a continuum of student-centered to teacher-centered. The "not observed" rubric cell is scored as zero while the adjacent cell is assigned a one, continuing to the last cell, the most student-centered cell, which is assigned a four. The highest possible score on the rubric is 24, and the lowest is 0, which indicates no observed evidence of inquiry-based practices. STIR reliability is reported as strong with r=1 (Beerer & Bodzin, 2004a). To determine a STIR score, each teacher was observed three times during a 12-week period. STIR observations were unscheduled to provide as accurate a picture as possible of normal teaching pedagogy and procedures. During the observations, the researcher assumed the role of "complete observer," only gathering data and interacting casually and nondirectly with the students and teacher during the observation. The STIR data for each teacher was reported as the total score of the three lesson observations.

Content learning outcomes for students were collected from a standards-based exam, the Oregon State Standards Benchmark II Test of Science Knowledge, given during the fifth grade year. The Oregon science standards and assessments are based on the NSES. The Oregon Science Assessment consists of multiple-choice questions in the areas of earth science, life science, and physical science (Oregon Department of Education, 2005). The scores were reported in Rasch units. Student inquiry skills data was collected from a performance-based, rubric-scored, inquiry work sample, which measures student ability to perform and communicate science inquiry as identified by the National Science Education Standards. The inquiry work sample's four parts were each scored on a six-point rubric designed by Oregon science teachers and the Oregon Department of Education. Scores ranged from a 6, exemplary, to a 1, no inquiry requirements utilized. To gather student inquiry data for this study, a total score of the inquiry parts was determined for each student, and a class total score mean was calculated. The validity of the science measures is reported by the Oregon State Department of Education as 0.80 to 0.85, depending on the compared measure; reliability is reported as 0.889 (Oregon Department of Education, 2005).

A qualitative component, the Informational Questionnaire (IQ), asked teachers about their science learning pedagogy, science teaching pedagogy, and the importance of science in their curriculum. The IQ was expected to provide greater depth and context to the quantitative data, creating a more complete overview of teachers' science teaching beliefs and practice through narrative responses to open-ended questions. To develop the IQ, questions were selected from established sources, such as the Third International Mathematics and Science Study (National Center for Education Statistics, 2004) and Newmann and McNeil (1997) surveys used to measure pedagogy and science attitudes. Questions focused on science pedagogy and the importance of science and were modified to an open-ended response format. To ensure quality, a draft of the instrument was developed and piloted. The pilot included interview sessions to ensure that the teachers correctly interpreted the questions. Pilot test data was used to determine item reliability, reducing the IQ to eight questions. Before the IQ was given to the study sample group, a final review was conducted to confirm that teachers had consistent understanding of each question. Cronbach's alpha determined a 0.81 reliability value. The IQ included questions such as the following:

- Do you think science is important? Explain.
- Describe how you present and teach science content.
- What percent of your science class time is spent on activity-based learning?

To begin the data collection process, the research project was explained, and the SAS and IQ were administered. Teaching observations took place over a 12-week period. Each teacher was observed teaching three science lessons, and each lesson's pedagogy was scored with the STIR. Some anecdotal data was also recorded following each observation. School administrators provided student content and inquiry assessment data.

Subjects

The sample consisted of 15 fifth grade teachers and their 439 students from a spectrum of socioeconomic and ethnic groups in schools in northeastern Oregon. Actual data on ethnicity and socioeconomics in each classroom was not collected, but data from the Oregon Department of Education (2005) provided a comparison of the study schools. As a reflection of socioeconomic and ethnic demographics of participants in this study, Hispanic and Native American student populations in several study schools were greater than the Oregon overall percentages, and the percentage of free and reduced lunch students varied from a low of 26% to a high of 73%, compared to the overall Oregon range of 10% to 86%. Two of the study schools had over 70% free and reduced lunch students.

Results and Analysis

The data, displayed in Table 1, from each measure yields little overt information.

Table 1. Data Summary

Teacher	SAS Total Scores	STIR Total	Student Inquiry Mean Score	Content Mean (Rasch Units)
1	79	3	12.0	226.5
2	115	8	12.0	219.0
3	84	16	18.0	224.6
4	91	7	16.0	223.9
5	90	7	16.0	224.3
6	89	10	12.0	226.3
7	94	12	13.2	231.0
8	84	8	12.8	231.0
9	103	0	14.0	227.5
10	97	11	15.0	224.8
11	86	22	16.0	228.4
12	65	0	12.0	227.7
13	100	16	14.0	220.6
14	76	15	17.0	233.4
15	95	42	18.0	224.5

To investigate relationships, correlations are calculated between teacher variables pedagogy (STIR) and science teaching attitudes (SAS) and the student learning outcome means—content and inquiry. Table 2 summarizes the correlation results.

Table 2. Teaching Pedagogy/Teacher Attitude Correlation Results (n=15)

Correlation Combination		Pearson Correlation Coefficient	Statistical Significance P Value (2-tailed)
STIR Total	SAS Total	-.043	.880
STIR Total	Content Mean	- .080	.777
STIR Total	Inquiry Mean	+ .648	.009*
SAS Total	Content Mean	- .623	.013*
SAS Total	Inquiry Mean	- .335	.222

*** significant relationship**

The correlations indicate that neither positive nor negative attitudes about science teaching are related to the teaching pedagogy utilized by participant teachers. The raw data indicates strong positive attitudes about science teaching but few inquiry teaching practices. Further information, anecdotal and IQ responses, shows major differences between what the teachers say they do and believe and what the researcher observed them doing in the classroom. Of the 15 teachers, 14 describe their teaching pedagogy using words such as *teacher facilitator*, *hands-on*, *experiments*, *inquiry*, and *high interest activities*—all inquiry-related descriptions. STIR data indicates, however, that teaching pedagogy is very non-inquiry.

A second correlation result examines the relationship between pedagogy (STIR) and student achievement, both content and inquiry. The correlation coefficient of +0.648 between STIR and student inquiry indicates a moderate positive correlation between teaching inquiry pedagogy and student inquiry outcomes and meets the established criteria for significance (correlation coefficient 0.514 or greater shows significance at the 0.05 level) with a corresponding p value of 0.009. The results indicate that inquiry teaching pedagogy is related to student success in inquiry learning; however, the correlation of inquiry teaching, STIR data, and student content scores indicates neither a positive nor a negative relationship.

A teacher attitudes and student content knowledge correlation of -0.623 indicates a moderate negative relationship between teacher attitudes about science teaching and student content knowledge and meets the established criteria for statistical significance with a resulting p value of 0.013. The negative correlation value indicates an inverse relationship between science teaching attitudes and student success on content knowledge exams. Teachers with lower SAS scores, meaning more negative attitudes about science teaching, have students who did well on content exams; conversely, teachers who have more positive attitudes about science teaching have students who did poorly on science content exams.

A correlation coefficient value of -0.335 indicates a moderate inverse relationship between SAS scores and student inquiry scores. Students who did well with inquiry had teachers with low SAS scores or more negative attitudes about science teaching; inversely, the students of teachers with positive attitudes about science did poorly with inquiry.

Table 3 summarizes the results of STIR, SAS, and student inquiry multiple regression results. The teacher variables (pedagogy and attitude) are considered to be predictors of student outcomes.

Table 3. Independent Variables: STIR and SAS; Dependent Variable: Student Inquiry Scores (n=15)

R	R Squared	Adjusted R Squared	Std Error of the Est.
.659	.435	.340	1.787

	Unstandardized Coefficient		Standardized Coefficients		
	B	Std. Error	Beta	t	Significant (p value)
Constant	15.163	3.607		4.203	0.01
SAS Total	2.58E-02	.040	-.141	-.641	.533
STIR Total	0.142	.047	.665	3.031	.010**

(Dependent variable: student inquiry mean scores)

(significant at the 0.05 level)**

The regression coefficient value 0.659 indicates a strong relationship among STIR, SAS, and student inquiry, accounting for 43% of the variance in the relationship. A further breakdown of the calculation reveals that the relationship between the STIR and student inquiry is statistically significant with a p value of 0.010. The Beta values indicate that the strength of the STIR, SAS, and student inquiry relationship is due to the STIR and inquiry relationship.

Table 4 summarizes the results of the STIR, SAS, and student content knowledge multiple regression. The teacher variables (pedagogy and attitude) are considered to be predictors of student outcomes.

Table 4. Independent Variable: STIR and SAS; Dependent Variables: Student Content Scores (n = 15)

R	R Squared	Adjusted R Squared	Std Error of the Est.
.623	.388	.286	3.18

	Unstandardized Coefficient		Standardized Coefficients		
	B	Std. Error	Beta	t	Significant (p value)
Constant	243.73	6.42		35.954	0.00
SAS Total	4.28E-03	.083	0.12	.052	.960
STIR Total	-0.196	.072	-.624	-2.74	0.018**

(Dependent variable: student content scores)

(significant at 0.05 level)**

The regression coefficient value 0.623 indicates a strong relationship among STIR, SAS, and student content scores, accounting for 39% of the variance in the relationship. A further breakdown of the calculation reveals that the relationship between the STIR and student inquiry is statistically significant with a p value of 0.018. The strength of the relationship among the STIR, SAS, and student content, as indicated by the Beta values, is due to the STIR and content score relationship; the SAS values influence the statistical relationship minimally.

Summary

A major finding is a negative relationship between science teaching attitudes and student success on content knowledge assessments. Inquiry-based teaching pedagogy relates to students' success in performing science inquiry but not to learning content knowledge. Teacher attitudes about science teaching show no statistical relationship to science teaching pedagogy.

Discussion, Conclusions, and Recommendations

This study provides a unique look at the impact of teacher factors, attitude and pedagogy, on student learning. The results suggest several important findings.

The analysis of the relationship between science teaching attitudes and science teaching pedagogy addressed by the first research question determines that science teaching attitudes are not related to the utilization of inquiry as a science teaching pedagogy with no statistical correlation between the variables. An interesting finding is the contrast between teacher reported pedagogy and observed pedagogy. Study participants generally report mostly positive attitudes about science teaching, and teachers use words such as *teacher facilitator* and *hands-on science* to describe their science teaching strategies. Classroom observation data, however, finds few teaching methods relating to these descriptors. The disconnection may be attributed to a difference in the teachers' understanding of hands-on and inquiry teaching pedagogy from the accepted definitions and practices. Teachers may view a teacher-directed activity or teacher-performed demonstration as being inquiry teaching or a question-and-answer session as inquiry. Another possibility is that teachers want to impress the researcher by using science inquiry jargon and appearing to be "good" science teachers.

The second research question addresses the relationship between pedagogy and student learning. A strong positive relationship between inquiry-based science teaching pedagogy and student achievement in inquiry exists, but no relationship, positive or negative, between inquiry-based science teaching pedagogy and achievement in science content is evident. Teachers may not be skillful in combining content learning effectively with inquiry pedagogy, or state-mandated tests might affect how science is taught. To explain this, the effect that forced student assessments may have on teaching practices should be considered in further research. Classroom observation data shows few inquiry-based teachers, but the student inquiry success of those who do use inquiry has a strong positive correlation to the inquiry teaching pedagogy. Teachers who practice inquiry teaching strategies can be expected to have students who are able to successfully conduct science inquiry.

The last research question investigates the relationship between science teaching attitudes and student learning. Contrary to other research, this study finds that teachers' science teaching attitudes are not statistically related to student academic success in either content knowledge or inquiry process learning. Teacher science attitudes vary from being somewhat positive to mostly positive; however, student scores on state assessments are mediocre to poor. Teachers with positive attitudes about science may have low achieving students, and conversely, some teachers with negative attitudes about science may have students who are high achieving. Two explanations for why positive science teaching attitudes do not predict high student achievement, as found by this study, are as follows:

1. Teachers inaccurately present their actual beliefs and attitudes about science teaching. Teachers may wish to present themselves as positive pro-science teachers when they are not.
2. Teachers may have positive attitudes about science teaching, but they do not have the pedagogical skills needed for inquiry-based instruction.

An additional explanation of the lack of student achievement, based on the researcher's casual observations, is that the science curriculum taught may not be aligned with the NSES and the assessment instruments. Some teachers teach their favorite units, even though the unit content is not supported by the NSES.

Science teaching qualities of elementary teachers can determine the success of students in learning science, as suggested by numerous studies and acknowledged by the NSES. Science teaching pedagogy and student success must be considered because one of the main goals of science education improvement is to create opportunities for students to learn science in the context of real-life, inquiry-based experiences. Data reveals that students are not learning science content and are not successful with inquiry. Teacher experience and skill with science inquiry may not provide the expertise required to teach using inquiry. Teachers may believe they are teaching science using inquiry pedagogy and meeting standards, but they are, in actuality, extending the teacher-centered instructional methods. Further research is needed to explore teacher misunderstanding of inquiry pedagogy, as well as how teachers can gain the skills and confidence to teach science content through inquiry pedagogy. The science curriculum utilized by elementary classroom teachers is another area in which more information is needed.

Overall, the results of this study add to the literature addressing the impact of teacher attitudes and pedagogy on student learning. Although the teacher traits examined are limited, it is informative to find that teacher pedagogy and student success with inquiry learning shows a strong relationship. It is also important to note that teacher attitudes show no relationship to teaching pedagogy or student learning success.

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