

Elementary Science Methods: Measuring and Developing Student Views About the Nature of Science

INTRODUCTION

The nature of science, within a 3-credit hour elementary science methods course, is characterized by two broad themes - the nature of scientific inquiry and the nature of scientific knowledge. Scientific inquiry is described, in general terms, as processes used to generate and test scientific knowledge. These processes include stating a research question, hypothesizing, observation, collection-recording-interpretation of data, and drawing conclusions. The nature of scientific knowledge, as defined by Rubba & Anderson (1978), is portrayed as developmental (tentative), testable (capable of empirical test), creative (partially a product of human creativity), and unified (the specialized sciences contribute to an interrelated network of laws, theories, and concepts). Although there is a distinction made between these two areas of the nature of science for purposes of discussion, the interdependent nature of these two areas is made evident. Defining the nature of science in this way has proven useful with this population of students not only because their understanding of these aspects of the nature of science is very limited, but because these definitions are applicable to the teaching of elementary grade students.

During the course, strategies are used to reveal, change, and measure student views about the nature of science prior to, during, and upon completion of the course. Various teaching approaches and activities are integrated within the course to help students develop more adequate views about the nature of science. In addition to strategies designed to develop understandings about the nature of science, an attempt is made to help these students relate what they learned in their methods class about the nature of science to the teaching of elementary science.

Strategies used throughout the semester enhance the learning of pre-service teachers in a number of ways. By modeling effective teaching strategies for use with elementary students, providing “real” science experiences for pre-service teachers to construct their own knowledge of the nature of science, allowing time for reflection on new understandings, and making an explicit connection between the learning of pre-service and elementary students, pre-service teachers not only develop their own understandings while learning effective teaching strategies; they also gain insights about the ways that their future students experience learning.

The study of the nature of science throughout the semester is addressed through the broader context of scientific literacy. The definition of scientific literacy used in this science methods course is characterized by four general areas. These areas are: 1) basic understandings of the knowledge base of science, 2) the understanding of and ability to use scientific processes, 3) the use of higher order thinking skills, and 4) scientific attitudes and values. Specific attitudes and values discussed include objectivity, openness, the value of trial and error, intellectual honesty, and tolerance for ambiguity.

Description of the Course and the Student Population

During the one-semester elementary science methods course, students receive direct classroom instruction for a period of 12 weeks and complete a 4-week field experience in the schools. The class meets for a period of 75 minutes, twice weekly. Major course requirements and experiences include the following: 1) daily hands-on, inquiry learning, 2) teaching a learning cycle lesson to peers and to elementary students, 3) conducting a controlled research experiment involving observations made over time, writing a research report, and sharing results with peers, 4) field assignments involving science teaching, interviewing children for a variety of purposes, and describing science programs used in schools and classrooms, 5) development of a unit that integrates

science with other subject areas, 6) quizzes and a final exam. Following several of these experiences, students were required to summarize their reflections about what they learned about science and science teaching.

Students enrolled in this methods course are college seniors and graduate students seeking teacher certification. The college seniors take this course as part of a block of five methods courses. The vast majority of these students take the methods block the semester before student teaching.

Science content coursework, at minimum, taken prior to the science methods course consists of a 4-credit biology course taught by Arts and Sciences faculty and two, 4-credit physical science courses taught by science education faculty specifically for elementary education majors. Each of these three science courses has a laboratory component.

DESCRIPTION OF TEACHING METHODS

Strategies to develop more accurate conceptions of the nature of science are integrated throughout the course. Teaching approaches used for this purpose include: 1) learning cycle lessons taught to peers and to elementary students (including a reflective analysis about what was learned about science and science teaching), 2) the design and implementation of a long-range experiment, a written research report, and sharing of results with peers, 3) a follow-up reflective analysis of the long-range experiment, summarizing what was learned about the nature of scientific inquiry and how such an experiment might be structured in an elementary classroom, and 4) a quiz on the nature of science.

Learning Cycle

One strategy used to develop student understanding of the nature of science is the learning cycle approach. This approach is taught and modeled by the instructor during the beginning of the

- ___ Questions based upon exploration activities were asked.
- ___ Probing was used when student responses were limited.
- ___ Teachers effectively used wait time.
- ___ Learners were clearly led to a deduction of concept through teacher-facilitated discussion.
- ___ Almost all students were involved in discussion of concept.
- ___ Concept was clearly defined verbally and in writing.
- ___ Concept was visually represented (drawings or use of actual materials).
- ___ Concept definition was related back to each exploration activity.
- ___ Science information presented was accurate.

APPLICATION PHASE

- ___ Learners verbalized concept definition as it applied to new situation.
- ___ Learners applied concept to real-life situation.
- ___ Copy of lesson provided to classmates.
- ___ Self-analysis completed.

As part this requirement, students write a reflective analysis about what they learned about science and science teaching as a result of using the learning cycle approach to teach a peer lesson.

Questions to which students respond are shown in Figure 2.

Figure 2. Reflective Analysis of Peer Lesson

1. Describe what you believe went very well (strengths of the lesson). Explain your response.
2. Would you do anything differently next time you teach the same lesson? If so, what would you do differently and why? If not, why?
3. Describe what you have learned about science teaching as a result of teaching this lesson.
4. Explain any change(s) in attitudes or beliefs about science teaching that took place as a result of planning and teaching this lesson.
5. Describe any fears that existed about teaching this lesson to your peers. Were these fears realized or diminished as a result of teaching the lesson?
6. Free comment.....

Students' peer lessons are scheduled throughout the semester. The seventy-five minute class period allow for two lessons to be taught during one period. The length of peer lessons averages one half hour. An attempt is made to schedule all of the peer lessons prior to the field experience, but

this is not always possible. The idea is to allow students to “practice” with their peers prior to teaching a learning cycle lesson with elementary students during the field experience.

Long-Range Research Experiment

Another teaching strategy which results in improved understanding of the nature of science is to have students conduct a long-range experiment. Students, working alone or in groups of 2-4, are in complete control of this experience, from the development of a research question which interests them to the formulation of a hypothesis, the design of a controlled experiment, the collection and recording of data, the interpretation of results, and the drawing of conclusions based on their results.

Students are required to submit a written report of their work and share their results with the “scientific community” of their peers. The guidelines for the written report are presented in Figure 3. Examples of research questions developed and investigated by students are shown in Figure 4.

Figure 3. Guidelines of Long-Range Experiment

1. Research question - state, in specific terms, the question you are investigating.
 2. Hypothesis - state your “educated guesses” in regard to the answer to the research question.
 3. Materials - list all materials and amounts/number of materials used to conduct the experiment.
 4. Procedure - list, step by step, the following information:
 - a. How you set up the experiment, identifying the control conditions and variable conditions of your experiment.
 - b. Method you used to collect and record data.
- * Procedures should be written clearly enough so that other “scientists” could easily replicate the experiment.
5. Record of data collected - include all data collected during the experiment, in an easy to interpret form. This form could be a table, graph, organized notes, photographs, or a combination of these. Be as specific as possible in your descriptions of data.
 6. Results - write a narrative which describes the data collected throughout the experiment. Information presented in visual displays should be interpreted for the reader.
 7. Conclusions - begin this part of your report by stating whether the hypothesis is accepted or rejected. State your reasons for this decision. Explain what the “research community” can learn from the results of your experiment. Include any research questions which you would recommend

for follow-up or future research about the same topic or similar topics.

8. Bibliography - list references that were used to help you conduct any step of the experiment.

Figure 4. Example Student Research Questions

1. How does acidity affect the quality of plant life?
2. How will the respiration rate of goldfish be affected by a temperature decrease of 5 degrees Fahrenheit?
3. Which household cleaner will be most effective at stopping bacterial growth?
4. Will a banana brown faster on a counter in the open air, on a counter in a brown paper bag, or in the refrigerator?
5. How does the addition of oil affect the evaporation rate of water?

The class period during which students submit their written research report and make an oral presentation of their research study to classmates, they are given a follow-up written assignment to be due the following class period. This follow-up assignment requires that students summarize the individual learning that occurred as a result of conducting the long-range experiment. The questions asked of students are, 1) What did you learn about the nature of scientific inquiry as a result of conducting this experiment? and 2) What are your ideas about structuring long-range experimentation and observation with elementary students?

The questions and instructions provided for this summary are open-ended. The intent of the instructor, employing a constructivist approach, is to assess learning about the nature of science "constructed" by students as a result of actually using the scientific inquiry process. For that reason, the students are asked to respond to the two questions immediately upon completion of the experiment, written report and oral presentation prior to any class discussion.

Constructivist Approach

A constructivist approach is used during the learning cycle lessons and long-range experiment by providing students with a common, first-hand experience upon which they construct their own

understandings about the nature of science. Topics related to the nature of science are not discussed by the instructor until students first have the opportunity to construct their own understandings.

Instructional emphasis is placed on the inquiry process of generating knowledge, the developmental, testable and creative nature of scientific knowledge, and the scientific attitudes and values of objectivity, openness, importance of basing conclusions on scientific evidence, intelligent "failure", and the social context of science. Instructions for the reflective analyses following both experiences are consistent with the constructivist approach in that students are provided with open-ended questions, which allow them to construct and synthesize their own learning.

Quiz: The Nature of Science

Once the long-range experiment and reflective analysis are completed and discussed, students take one of four quizzes given during the semester. The quiz requires students to react to the appropriateness of any one of the following three statements below: The results of my experiment proved that mold grows best under moist and warm conditions; The hypothesis of my experiment was wrong; or The results of my experiment are wrong. Students are also presented with the following scenario and asked to explain what it tells them about the nature of scientific knowledge: Scientists believed at one time that the earth was the center of the solar system. They now believe that the sun is the center.

In addition to these two questions, students are presented with a hypothetical situation in which an elementary student has set up an experiment with two control variables. Students are to read the scenario and then determine whether the conclusions of the experiment were valid. They are not told that there are two control variables. This scenario is as follows:

Clarietta Rutherford, a student at Mayfield Elementary School, developed the following research question, "How do the emotions of hate and love affect plant growth?" She plants Bermuda grass in

two separate containers and shows hate toward one plant and love toward the other. After three days, the plant toward which she showed love is thriving, a healthy green color, and several inches taller than the plant toward which she showed hate, which is visibly dying. She concluded from this experiment showing an emotion of hate toward a plant will have negative affects on the growth. When asked by her teacher if

Figure 5. Long-

The inquiry process generates more questions.

Having an open-

The inquiry process is a never ending search for knowledge.

The usefulness of the steps of the scientific method is evident.

Conclusions are often inconclusive and lead to other questions, hypotheses, and experiments.

Results can change each time you do an experiment.

When an experiment has been done many times, you should still say that the results "indicate" that....

Hypotheses are never wrong, they're just not supported by results.

Experiments don't fail you learn from results.

Inquiry involves creative thinking.

Science experiments can and should be simple.

An area of positive change that occurs as a result of students conducting the long range experiment, not reflected by Figure 5, concerns an internal shift in student belief systems that is very important to understanding the nature of science. Many of the students describe a shift in feelings from initially being very disappointed by having to reject their hypothesis to feelings of "it's really ok if the hypothesis is rejected". One student even said she was glad her hypothesis was rejected because of what she learned!

Another interesting result is that many students volunteer the information that the experience of conducting a long-range experiment was their first ever. One student said it was his second experience, the first being a 7th grade science fair project.

Conducting Long-Range Experiment With Elementary Students

Although many responses to the question, "What are your ideas about structuring long-range experimentation with elementary students?" relate to areas of learning not directly related to the nature

of science, such as structure of student groups and time issues, there are numerous and varied responses related to the nature of science. First, virtually every student notes the importance of doing long-range experimentation with elementary students. This in itself, is viewed as a remarkable and significant result of students conducting their own experiment in a methods course!

The most frequent response given is the importance of teaching kids that they have not failed if their experimental results are not what they expected. Another frequent response is the importance of kids being involved in the "creation" of the experiment from beginning to end. Several students mention the importance of having students develop their own questions to investigate. Other responses include the importance of teaching the processes of the scientific method, the relevance of experimentation to real life, development of clear research questions, hypothesizing, observation skills, the concept of controls and variables, methods of reliable data collection, and basing conclusions on experimental evidence.

The developmental, testable, and creative nature of scientific knowledge are represented in student responses to how long-range experimentation should be conducted with elementary students. The most significant growth in understanding, as reported by students, relates to the developmental nature of scientific knowledge.

Pre- and Post-Semester Measures of Student Views About the Nature of Science

Strategies are used to measure student views on the first and last day of class, in addition to views which have evolved during different times of the semester. The intent is to determine the extent and nature of change in student views about the nature of science and science teaching as a result of different classroom experiences and as a result of the combined classroom experiences during the semester.

Qualitative Measure

Students are asked to respond to the following two questions on the first and last day of class:

1) What is science? and 2) How do you think science should be taught at the elementary level?

The post-class responses to these questions reveal that students develop a much more complete understanding of the nature of science inquiry throughout the semester.

What is science? Comparison of pre-and post-response On the first day of class, students heavily emphasize the knowledge base of science in their definition of science and description of how it should be taught.. Their views about the processes of science are largely incomplete. Pre-and post-responses which relate to science content include the environment around you, the branches of science, use of fact, theories, and laws, way of describing world, physical and abstract view of world, an answer to many questions, and core subjects dealing with both known and unknown factors.

Most important, the number of student responses related to science as a process double from pre- to post-responses. Examples of process-oriented responses include a way of thinking about problems and curiosities, a method of discovery, an organized process in which ideas are tested, conducting an experiment to test a hypothesis, science is ever-changing and growing with new information, systematic approach to obtain knowledge, involves repeated trials, science is an ever-changing experience, discovery-inquiry-exploration, and going through a process that involves thinking and may involve attitudes and values.

How elementary science should be taught: Comparison of pre- and post-response There is a significant decrease in the number of content-oriented responses between pre- and post-response which relate to how elementary science should be taught. Examples of content-oriented responses include how science affects students, teaching basic facts, understanding vs memory, teaching of

concepts sequentially, and teaching about animals, habitats, substances, etc.

The number of responses which relate directly to teaching about the nature of science more than double from pre- to post-response. Examples of responses which relate to the nature of science include the following: teach basic methods of discovery, teach and apply scientific method, hands-on learning for the purpose of teaching process, as a process to gain knowledge, finding answers to self-questions, design own means of solving problems, and allow students to test theories.

Quantitative Measure

The Modified Nature of Scientific Knowledge Scale (MNSKS), developed by Meichtry (1992), is also used to measure and compare student views about four dimensions of the nature of scientific knowledge at the beginning and end of the semester. The four dimensions of scientific knowledge measured are the developmental, testable, creative, and unified nature of science. The MNSKS is a modified version of the Nature of Scientific Knowledge Scale (NSKS), developed by Rubba and Anderson (1978). Modifications of the NSKS, based on readability, reliability issues, and changing views of the nature of scientific knowledge, were made to create a more suitable instrument for use with middle school students.

The MNSKS is administered as a pre test on the first day of class after students responded to the questions "What is science" and "How should science be taught at the elementary level?". The MNSKS is administered as a post test on the last day of class after students have responded to the same two questions. In addition to an overall score on the MNSKS, mean scores for each of the four subscales (developmental, testable, creative, and unified) are available.

To determine whether the post-test mean scores of each of the four subscales of the MNSKS and the overall instrument differ significantly from pre-test mean scores, a paired comparison t-test

analysis is conducted. To determine statistical significance at the .05 level, t statistics are calculated.

Table 1. Paired-Comparison T-Test for the MNSKS Pre- and Post-Test

N=67

<u>Variable</u>	<u>Mean</u>	<u>STD Error</u>	<u>T PROB</u>
Developmental	1.31	0.38	0.0009
Testable	2.03	0.53	0.0003
Creative	2.30	0.56	0.0001
Unified	1.39	0.39	0.0007
MNSKS	6.49	1.19	0.0001

The results of the paired comparison t-test analysis, presented in Table 1 above , indicate that the increase in student understanding of the nature of scientific knowledge during the semester is statistically significant. The t statistic for each of the four subscales and the MNSKS are significant at the 0.001 level. These results, based on three classes of students during the same semester, are typical.

CONCLUSIONS

Given the demands on the one-semester elementary science methods course, instructors must be selective about what and how they will teach to best prepare students to teach science. Developing student understandings of the nature of science is one of many areas to be addressed. The results reported here indicate that students begin their methods course with understandings of the nature of science which are largely incomplete. The results also indicate the potential of developing much more complete understandings about the nature of science as a result of integrating teaching strategies throughout the semester designed, in part, to develop such understandings. The students enrolled in this elementary science methods course develop significantly greater understanding about the nature of

science throughout the semester, providing a sound foundation upon which students can continue to develop their understandings. These newly-acquired understandings, in turn, increase the potential that these prospective teachers will assist their own students in developing authentic understandings and beliefs related to the nature of science.

References

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