Students' Development of NOS Understanding: Integrating a Historical Case Study with the Revising of Models

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Abstract
An understanding of the nature of science (NOS) is critical to scientific literacy and the importance of teaching NOS is reiterated in current science education reform efforts. For this study, we designed an activity that integrates a historical case study with the practice of revising models and examined the changes in student thinking about the nature of science. Student pre- and post-tests from five teachers and six classrooms were collected and analyzed for 8 codes that indicate aspects of NOS understanding. Our findings showed some shifts in students' understanding of the tentative nature of science. We discuss these shifts and implications of this study for future research and curriculum development.

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Theoretical Framework

Two models for teaching NOS
- Provide students with opportunities to engage in and reflect on scientific practices
- Use historical case studies in instruction to illustrate nature of science concepts

Understandings about the NOS (NGSS Lead States, 2013, Appendix H)
- Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or interpretation of existing evidence.
- New technologies advance scientific knowledge.
- Scientific knowledge is a result of human endeavor, imagination, and creativity.

Research Question

What differences in students' ideas about how scientific knowledge changes are reported after participating in an activity that involves revising models of the tree of life?

Curriculum

How do small things make a big difference? Curriculum Unit
Contains six lessons about the tree of life, microbes, and microbial ecology. Lessons 1 and 2 cover concepts about the nature of science.
- Students work through an interactive historical case study in which they revise several models of the tree of life based on new information.
  - Lesson 1: How did the tree of life change through history?
  - Lesson 2: What is the current tree of life model?

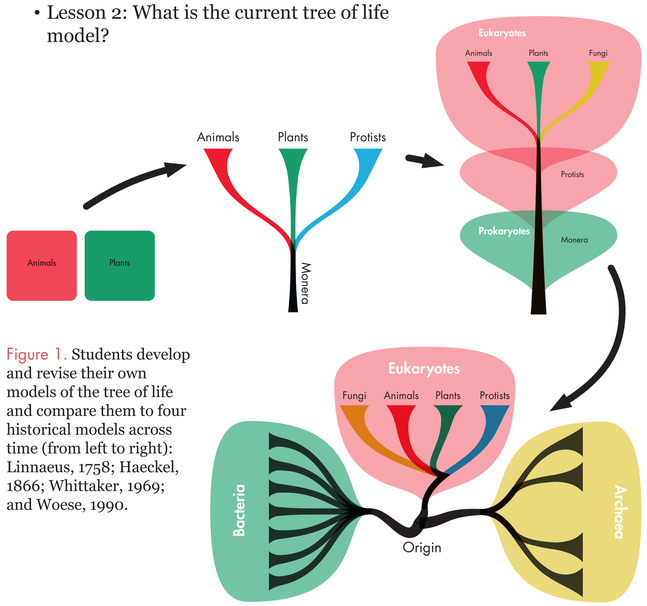


Figure 1. Students develop and revise their own models of the tree of life and compare them to four historical models across time (from left to right): Linnaeus, 1758; Haeckel, 1866; Whittaker, 1969; and Woese, 1990.

Methodology

Table 1. This study included student artifacts from high school classrooms of five teachers.

Teacher	Grades	Class	School Setting	Workshop Attendance
S06	11-12	Zoology	Small Urban	Yes
J24	9	Accelerated Biology	Small Urban	No
K04	9	Accelerated Biology	Small Urban	Yes
M23	9	Biology	Rural	No
K22	10-12	Biology II	Rural	Yes

Test Question: "Explain how and why scientific knowledge changes over time. Use specific reasons and examples in your explanation."

Table 2. Student responses were coded using eight codes that indicate NOS understandings (inter-rater reliability 87.5%).

Code	Student Examples
Get new information (learn more)	• "When scientists learn new information" • "When new experiments are done" • "Because scientists gain new knowledge as they study it more"
Advances in technology	• "Scientific knowledge changes over time due to technological advancement, as with the invention of microscopes..." • "The more advanced a piece of equipment is the more we can explore something."
New discoveries	• "Scientific knowledge changes over time because of new scientific discoveries." • "Scientists are always discovering new things."
Able to study things better (can investigate more deeply; better methods)	• "Scientific knowledge can change with the use of better microscopes because you can see what you haven't seen before." • "When technology is updated scientists can be more exact."
Models are revised	• "When building a model of DNA, the model changed multiple times until they found the information they needed." • "The tree of life changed and expanded a lot from the original model."
New ideas (frameworks; progressive thinking)	• "Scientific knowledge changes because of new findings which can usually be accredited to advances in technology or new ways of thinking" (example provided: tree of life model changes because of Darwin's theory of evolution) • "Models can also change if a new scientist develops a better theory."
Human endeavor (answer indicates agency of scientists)	• "Carl Woese used DNA sequences of microbes/ other organisms to change the tree of life model..." • "Scientists are constantly looking for the best method possible" • "Many different scientists study one thing"
Problems with current knowledge (or gaps in knowledge)	• "Scientific knowledge changes over time when new evidence has come out that disproves common hypotheses... because these hypotheses are now wrong."

Results

Figure 2. Graph of coded student pre and post test data shows shifts in student thinking about how scientific knowledge changes (pre-test, n=98; post-test, n=99).

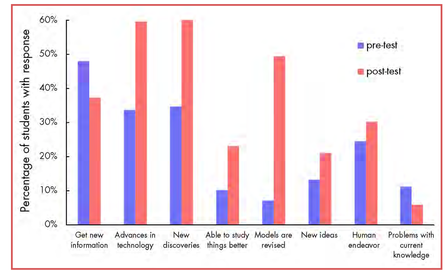
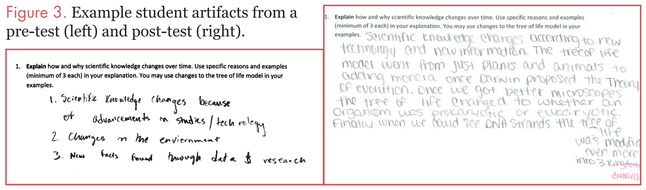


Figure 3. Example student artifacts from a pre-test (left) and post-test (right).



Discussion

- Pre-test results showed that a considerable portion of students were able to articulate some basic ideas about causes for changes in science understanding.
- Comparison of pre and post-test results showed an increased percentage of students that articulated causes for changes in scientific knowledge for six of eight codes.
- "Advances in technology," "new discoveries," "able to study things better," and "models are revised" were explicitly communicated throughout the activity and saw notable increase between pre- and post-tests.
- Results indicate the potential of instruction that blends the two approaches of being reflective about the practices and learning through historical case studies.

Figure 4. Teacher workshop on the curriculum unit *How do small things make a big difference?* Three of the five teachers in this study attended a workshop.

Next Steps

Further research
- Additional analyses: pre- and post-test data, audio data of student group discussions during the activity, audio data of teacher instruction.

Curriculum Revision Considerations
- Integrate more explicit opportunities for students to experience "problems with current knowledge."
- Students may benefit from a longer learning intervention with more explicit instruction to develop more sophisticated concepts of the nature of science.

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