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ABSTRACT

This paper examines how using a series of lessons developed from the history of research on sickle cell anemia affects preservice teacher conceptions of the nature of science (NOS). The importance of a pedagogy that has students do science through an integral use of the history of science is effective at enriching students' NOS views is presented. What is broadly meant to be the nature of science is discussed, and a brief overview of the sickle-cell case and the merits of the integral approach on affecting students' NOS views is presented. (KHR)

Using the History of Research on Sickle Cell Anemia to Affect Preservice Teachers' Conceptions of the Nature of Science

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I. Introduction

The purpose of my talk is to share with you one aspect of my ongoing dissertation work that examines how using a series of lessons developed from the history of research on sickle cell anemia affects preservice teacher conceptions of the nature of science (NOS). Today I will present an argument that supports why a pedagogy that has students "do science" through an integral use of the history of science is effective at enriching students' NOS views. I will first discuss what is broadly meant be the nature of science and provide a brief overview of my sickle-cell anemia case. Then I will discuss the merits of the integral approach on affecting students' NOS views. I will conclude by briefly discussing my empirical research that measures the effectiveness of this pedagogical approach.

A concern that is often expressed by science educators, philosophers and historians of science, and others is that students largely conceive of science as a body of factual content that is to be memorized (Duschl, 1990, Mathews, 1994). The problem is that this rather narrow conception ignores the importance of understanding the epistemology of science, that is "how we know" what we know. Broadly construed, the nature of science addresses aspects associated with the epistemology of science. This includes, for example, understanding how scientific knowledge is developed and validated (role of theories), that scientific knowledge is tentative, that it is subjective, and etc. Science educators have recognized for several decades that one goal of science education should be to improve students' understanding of the nature of science (e.g. Conant, 1947; Lederman, 1992; Rutherford, 1963; Russell, 1981; Trowbridge & Bybee, 1990). A fundamental reason for this is to disabuse students from the notion that science is simply a body of factual knowledge to be memorized and rather to have them appreciate science as a "way of knowing" supported by certain methods. This emphasis is further stressed in reform documents such as the Benchmarks for Scientific Literacy and National Science Education Standards (AAAS, 1993, 1990; NRC, 1996).

Several researchers (e.g. Abd-El-Khalick, 1998; Allchin, 2000, 1993; Duschl, 1990, Mathews, 1994; Monk & Osborne, 1997) claim that one way to foster an understanding of aspects of the nature of science is to more heavily integrate the history and philosophy of science into science lessons. One axis of this claim rests on the premise that the history of science provides a valuable context in which to properly interpret the philosophical nature of science issues. In general, two pedagogical methods have been adopted. The first I will term the "add-on" approach. This is exemplified by lessons in which episodes from the history and philosophy of science are tangential to the content being studied. The other method I call the "integral" approach. Here, the history and philosophy of science is used as the foundation for driving the pedagogy being used in the classroom. That is to say, issues of content and epistemology are imbedded in the historical "story" that forms the backbone of instruction.

We can further subdivide the integral approach as I have described into two types. One method involves using the history and philosophy of science by way of having students read historical stories or vignettes whereby students examine the work and conclusions of historical figures. The other method has students immerse themselves in the historical evidence by way of their recapitulating the work of such historical figures. My general thesis today is that this latter approach is more effective at enriching or changing students' nature of science views.

The integral approach I have developed to improve preservice elementary teachers' conceptions of the nature of science is based upon the history of research in understanding the disease sickle cell anemia. You may recall that sickle cell anemia is a disease of the red blood cells in which under low oxygen concentrations the erythrocytes assume a crescent shape. For pedagogical reasons, this disease is an ideal candidate to use to introduce students to how a biological phenomenon can be studied from several different yet related subdisciplines (e.g. genetics, ecology, molecular biology, etc.). This is because the disease has been well understood from all of these perspectives and the content is very accessible to the students. Moreover, the historical story and problems associated with the various perspectives lend themselves well to student problem solving work and to discussions about various fundamental issues in the nature of science.

Students are introduced to the disease as a mystery, and over the course of eight, two and a half hour long classes they examine problems which are developed from the subdisciplinary research to understand the disease. Unbeknownst to them, they recapitulate the reasoning that led Anthony C. Allison (1954) and his colleagues during the early to middle part of the twentieth century to their fundamental insights concerning how sickle cell anemia can be explained from these differing perspectives of biology.

To this end, the unit involves open-ended problems in which students must propose and defend their theories in light of the available evidence. A significant portion of each class incorporates group problem solving and discourse. Instructors facilitate by leading explicit discussions, particularly when the lessons highlight the targeted aspects of the nature of science that students' should be considering. We do this because research supports that students' conceptions of the nature of science are better enhanced when an explicit and reflective approach is adopted (Khishfe & Abd-El-Khalick, 2002).

Broadly stated, explicit/reflective approaches involve either the instructor of the course or aspects of the course material somehow ensuring that issues of the nature of science are actively considered in relation to the conceptual material being studied. This method differs markedly from implicit approaches to learning of the NOS in which the claim is that students will "pick up" such an understanding merely by virtue of learning the conceptual material or engaging in scientific processes (e.g. manipulating, measuring, etc.). The reflective portion denotes that students should be given opportunities to construct their own insights of the NOS issues, in contrast to simply having the instructor didactically "tell" students. In general, research (Khishfe & Abd-El-Khalick, 2002) that examines explicit/reflective versus implicit approaches to learning the NOS gives evidence that explicit/reflective approaches are more effective at enriching or changing students' views.

This sickle-cell unit is the last of a three-part sequence that makes up the course SCI 270, Life Science for Elementary Educators II at Western Michigan University. Though the course is not compulsory, the majority of students who enroll are satisfying a minor requirement in science and mathematics as a part of their elementary education experience. SCI 270 emphasizes genetics, molecular biology, and the sickle cell capstone. The companion life science course, SCI 170 emphasizes anatomy and physiology, ecology, and evolution. The relevant content for these courses comes directly from the Michigan State standards documents, which themselves were drafted in line with the national reform documents such as the Benchmarks for Scientific Literacy and the National Science Education Standards.

The class consists of 24 students, mostly female between the ages of 18-24 years old. These students generally have a strong aversion to science despite that they acknowledge they will one day teach science to elementary children.

Given this brief overview of the unit, let me now defend my claim that the type of integral approach I use to incorporate the history and philosophy of science is effective toward improving students' views of the nature of science. I will do this primarily by discussing the conceptual argument for this approach using specific examples from the case to illustrate my points. Following this, I will briefly mention how I am empirically measuring the efficacy of my unit.

II. Using History of Science to "Do-Science"

An objection that is often raised to using the history and philosophy of science to teach students both science content and the nature of science is loosely analogous to what the philosopher of science, Thomas Kuhn (1962, 1970) terms the incommensurability thesis in which scientists who operate under one paradigm cannot "see" the conceptual merit of another. That is, students judge the validity of historical conclusions or ways of thinking from their own contemporary (and often naïve) perspective. As such, it is difficult for them to "put on the required historical thinking cap" (Abd-El-Khalick & Lederman, 2000) to make sense of the larger nature of science morals exemplified by the historical context. Kuhn himself acknowledged that he was able to invest himself sufficiently to learn to "think like an Aristotelian", and therein lies the challenge to educators; to design and implement lessons using the history of science to facilitate students toward the active process of "putting on the historical thinking cap".

Consider a more passive method in which students are asked to read about the reasoning and conclusions of historical figures (e.g. Galen's claims that blood flow is unidirectional from the heart or that the left ventricle uses a flame to concoct vital spirits) and are asked to evaluate the legitimacy of those points of view. This often is the case when historical vignettes, or short stories, are used to integrate the history of science into the lessons. The problem with this approach is that such methods understandably invite students to immediately place the historical view they have read about in tandem or in parallel with their own antecedently developed views of the nature of science (e.g. that the heart circulates blood). As such, it is understandable that students may view historical ways of thinking as misguided or foolish.

The integral method I have developed based on the history of research in sickle cell anemia has students invest themselves in the material by way of their recapitulating the work of several scientists who developed an understanding of the phenomenon. Through this approach, students engage in numerous active processes, for example examining evidence, constructing explanations, suggesting further avenues for inquiry and conceptualizing new problems.

The advantage of having students actively engage with the historical problems or evidence is aligned with researchers (e.g. Abd-El-Khalick, Bell, & Lederman (1998); Abd-El-Khalick & Lederman, 2000) who claim that a view of the nature of science is something that the students cognitively construct. As such, lessons that use the history of science should be designed so that through examining the historical evidence, students are given several opportunities to invest in the material through active processes such that they potentially reconstruct their own views of science.

Under constructivist tenets (Piaget, 1959), we presume that students enter our science classes with conceptions of science that are a product of their prior experiences and knowledge. Throughout the course of the sickle cell unit, students are provided evidence for them to consider toward constructing explanations, or provisional theories. Part of the experience in this problem solving work involves the instructor providing probing questions to have students consider the ramifications of their work in the problems to more general issues of the nature of science. The answers to these questions often conflict with students' preconceived views, and as such the experience frequently initiates what may be broadly thought of as a "conceptual disequilibrium". Further explorations then allow students to examine their newly developed conceptions of (the nature of) science by way of providing them with subsequent historically-situated problems through which the insights they gain reinforce those conceptions. To borrow from the tenets of the conceptual change model (Posner, Strike, Hewson & Gertzog, 1982; Strike & Posner, 1992), the method provides ample situations that are fruitful and intelligible for students to test their new conceptions.

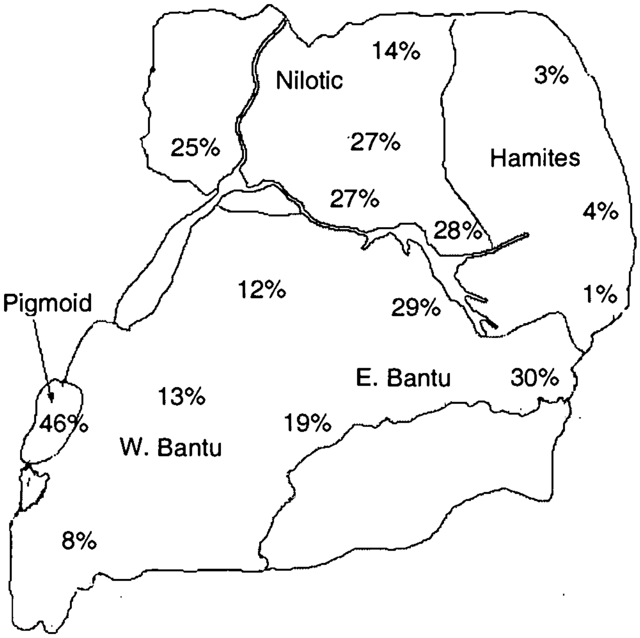

Figure 1. Frequencies of sickle-cell allele in Uganda, circa 1949.

For example, it is common that students begin the unit with the naïve view that science involves the search for truths, and as such, they hold the conception that theories are "proven" and unchanging entities in science. During the first class on evolution, students are challenged to construct a provisional theory to account for the varying and unexpectedly high frequencies of mystery disease (sickle cell) carriers in the country of Uganda (figure 1). From their prior class in genetics, they conclude that the debilitating nature of the mystery disease would effectively result in the near removal of the gene that causes it from a population of interbreeding individuals. Thus, to see such varying and high frequencies of carriers of the disease existing in the country of Uganda is an anomaly that cries out for explanation. The evidence they consider during this class (ethnographic and topographical data) strongly supports that the phenomenon is likely due to a combination of selective mutation and varying gene flow (via intermarriage).

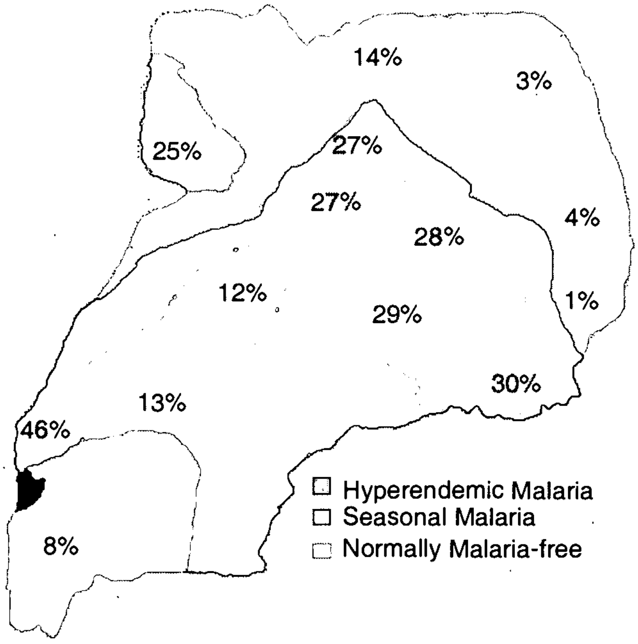

Figure 2. Distribution of malaria in Uganda, circa 1949.

In the beginning of the second evolution class, students are provided supplemental data from the hematologic work in the 1940's done to quantify the presence of a related blood disease, malaria (figure 2). When they examine their earlier frequency maps in conjunction with the malarial data, they see a strong correlation between the two. Students are also given the results from an observational study done by Anthony Allison in which he compared the severity of malaria in sickle cell and normal children (table 1). This information establishes that there is definitive protection afforded against the malarial parasite.

Genetic Disposition	Total Children Examined	% w/ *falciparum* malaria	Parasite Density Index
Normal ("+/+")	247	46%	5.9
Carrier ("+/-")	43	28%	4.0

Table 1. Hematologic analysis of children from Uganda, circa 1949.

Using their experiences in these classes, students are encouraged to examine the power or validity of their earlier theories in light of new evidence and new insights they have gained. And by way of the instructor asking probing questions (e.g. "Has your theory to explain the high frequencies changed? Why or why not? What caused you to change? Given that you all had access to the same data, did you all come to the same explanation to account for the high frequencies? Why or why not?"), they are challenged to consider whether indeed science is associated with finding certainties or rather with constructing at best refutable explanations.

In sum, let me underscore the advantages of the approach I have briefly discussed. Having students actively recapitulate the work of historical scientists greater immerses students in the contextual material. The goal is that they, like the analogy drawn to Kuhn, will through this investment see the conceptual merit of the historical views and as such come to appreciate the larger nature of science morals exemplified by the history of science. Finally, this process embraces the notion that a view of the nature of science is something that students cognitively construct. The unit facilitates several opportunities for the students to essentially *reconstruct* their views of the nature of science through processes aligned with conceptual change tenets.

The aforementioned is not to say that such integral approaches that I have described do not have their limitations. By their very nature, these cases require more time to design and implement, and as such they may be prohibitive for teachers who are constrained by time and need to cover copious content.

However, it is possible for teachers to integrate the active processes in a format (e.g. using vignettes) that would be more conducive when such constraints exist. The important issue is to avoid having students passively read the conclusions or ways of thinking exhibited by the figures in the story and rather have the students recapitulate their work in some fashion. The point is to have the students immerse themselves in the same thinking approaches employed by the historical figures such that they derive their own (likely similar) conclusions.

III Evaluation

Let me briefly share with you an overview of the empirical portion of my dissertation that measures the effect of this sickle cell case on students' NOS conceptions. The research is best characterized as an evaluative intervention, which is to say that I am measuring the effect of an instructional unit by using a pre/post test design. It uses as its main instrument a modified version of the open-ended survey, VNOS (Views of the Nature of Science) developed by Norm Lederman in the early 1990's (1992) and subsequently modified over the next decade (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

The survey (Appendix A) consists of open-ended questions about various aspects of the nature of science (from a context unrelated to sickle cell anemia), and it is designed to allow students to reflect upon those questions and respond in their own words in the space provided. In tandem with the VNOS survey, follow-up, semi-structured interviews are used to ensure validity of the survey and to gain additional information about student's idiosyncratic responses (Lederman & O'Malley, 1990).

Students' responses to the survey are characterized into emergent themes for each NOS aspect. These themes generally range from more naïve to more informed regarding each issue in the nature of science. Change attributable to the sickle cell unit in a student's NOS view requires both a shift in their theme about an issue in the NOS as revealed from their pre to post-survey answers and evidence in their post survey that the unit was responsible for their post view in the form of a valid example from their relevant sickle cell work.

Though I am in the process of completing the first round of analyses of the data, I can say anecdotally at this time that for certain aspects of the nature of science, a significant percentage of students' views were changed from relatively naïve to relatively more informed, and moreover, students were able to provide examples from the sickle cell unit to substantiate their views expressed on the survey.

Appendix A – Modified VNOS Survey

1. Often in science, we hear words like "theories" used to describe scientific knowledge.

    (a) What is a theory?
    (b) How are theories developed?
    (c) Can you give an example of a scientific theory?

2. After scientists have developed a theory (e.g., atomic theory. theory of evolution), does the theory ever change?

    If you believe that scientific theories do not change:

    (a) Explain why theories do not change.
    (b) Defend your answer with examples.

    If you believe that scientific theories do change:

    (a) Explain why (and how) you think theories change?
    (b) Give an example from your experience in which a theory has changed.

3. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

4. Scientists often conduct experiments to gather data. In general, an experiment is a controlled intervention that involves manipulating something of interest by holding certain things constant and varying others.

   Does the development of scientific knowledge **require** scientists to do experiments?

   (a) If yes, explain why, and give an example to defend your position.
   (b) If no, explain why, and give an example to defend your position.

5. It is believed that about 65 million years ago the dinosaurs became extinct. Of the reasons formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second explanation, formulated by another group of scientists, suggests that massive and violent volcanic eruption were responsible for the extinction.

   (a) How are these **different conclusions** possible if all of these scientists have access to and use the **same set of data** to derive their conclusions?
   (b) Can you give an example from your experience in science when this same scenario has occurred?

6. Scientists have been working to identify the sequence of DNA located in the human chromosomes. Some claim that this project will reveal a complete understanding of how the body works.

   (a) Do you agree or disagree with this statement? Why or why not?

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