DOCUMENT RESUME

ED 418 887		SE 061 390

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TITLE	Biology and Physics Students' Beliefs about Science and Science Learning in Non-Traditional Classrooms.
PUB DATE	1998-04-00
NOTE	22p.; Paper presented at the Annual Meeting of the American Educational Research Association (San Diego, CA, April, 1998).
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Attitudes; Biology; Cognitive Style; *Concept Formation; *Constructivism (Learning); Elementary School Teachers; *Epistemology; Higher Education; Inquiry; Learning Strategies; Misconceptions; Physics; Preservice Teacher Education; Problem Solving; *Science Education
IDENTIFIERS	*Meaning Construction; *Nature of Science

ABSTRACT

The knowledge that students bring to the classroom has been a well-studied domain. The types of knowledge studied have included content knowledge as well as epistemological beliefs that students hold. This study focuses specifically on preservice elementary education students' understanding of science and science learning as a meaning-making activity. Student reflection books were used to describe these beliefs during a 15-week, nontraditional, inquiry-based biology or physics course. A coding scheme was developed to describe the students' beliefs about science and science learning as a meaning-making activity. Using this scheme, beliefs about science were compared with beliefs about learning. Student beliefs of science making were different from their beliefs about science learning, possibly owing to their firmer beliefs about science teaching. In addition, the beliefs that students held about science learning changed during the course. (Author)

Biology and Physics Students' Beliefs about Science and Science Learning in Non-Traditional Classrooms

by

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Abstract

The knowledge that students bring to the classroom has been a well-studied domain. The types of knowledge studied have included content knowledge (e.g. Osborne. & Freyberg, 1985) as well as epistemological beliefs that students hold (e.g. Songer & Linn, 1991). In this study, we will focus specifically on pre-service elementary education students' understanding of science and science learning as a meaning-making activity. Student reflection books were used to describe these beliefs during a fifteen-week, non-traditional, inquiry-based biology or physics course. A coding scheme was developed to describe the students' beliefs about science and science learning as a meaning-making activity. Using this scheme, beliefs about science were compared to beliefs about learning. Student beliefs of science making were different than their beliefs of science learning possibly owing to their firmer beliefs about science teaching. In addition, the beliefs that students held about science learning changed during the course.

INTRODUCTION

The prevalent view in science education is that the learner is in an act of constructing knowledge based on what ideas he or she brings into the classroom. Preconceptions or alternative conceptions that students hold before instruction are crucial to facilitating the construction of new conceptions (Posner, Strike, Hewson & Gertzog, 1982; Ausubel, Novak & Hanesian, 1978). Learning can be viewed as an attempt by teachers to help to facilitate change from students' everyday knowledge to more scientific knowledge. In this model of scientific instruction, the learner is expected to manipulate the ideas he/she has to fit new situations and to integrate these ideas into coherent structures. However, in order for students to change their everyday knowledge to more scientific knowledge, not only does their understanding of phenomena have to change, but notions about science have to change as well (Edmondson & Novak, 1993). In addition to studying the scientific content knowledge students bring to the classroom, researchers have also begun to investigate the importance of students' epistemological beliefs on science learning (Songer & Linn, 1991; Windshitl & Andre, 1998). In this paper, we are interested specifically in describing the beliefs that students bring to the classroom of science and science learning as a meaning-making activity and how these beliefs about science may differ from beliefs about learning.

To understand why students' beliefs about learning and science might be impacted in a constructivist classroom, it is helpful to look at Vygotsky's (1978) Zone of Proximal Development (ZPD). The theory behind Vygotsky's notion of the Zone of Proximal Development (ZPD) is that learning precedes development and that development is driven by the need to learn. A student may be at a particular point in development with certain abilities. To get beyond this point, the student needs a task to drive him/her to develop new abilities. The role of the teacher is to model the new ability that the student needs to develop, and to provide "scaffolding" to the student's existing abilities. In time, the student's ZPD develops into these new abilities and arrives at a different point in development.

This model of development provides a dynamic social nature to learning that focuses on how participants at different stages of development can work together. It also assumes that what the students are developing are new abilities (Moll, 1994).

As a simple example, consider a teacher trying to teach students how to make a grilled cheese sandwich. The teacher might start by making the sandwich while focusing the students' attention on particular key points of grilled cheese sandwich making. Then, the students will be allowed to make the sandwiches in groups with help from the teacher. The teacher will refocus the students on particular aspects of sandwich grilling while they are working. For example, the teacher might remind the students to heat the pan before grilling or when to turn the sandwich over. As the students practice, they will no longer need the teacher to remind them and will be able to make the sandwich on their own. In addition, they will have arrived at a different point in their sandwich-making development, now able to begin to make new kinds of sandwiches.

Of course, understanding science is a bit more complex than making a grilled cheese sandwich. However, this example demonstrates that the ZPD describes learning as part of an activity that involves the development of new abilities (Moll, 1994). For example, learning using the ZPD has been particularly successful in domains such as reading, writing, and mathematics (Moll, 1994). In these domains, the focus is on providing the students with activities in which the students have the opportunity to develop and expand on their abilities to read, write and do mathematics. The ZPD does not reflect learning the products of a particular domain, although those products may be learned as a part of development. For example, students will learn new vocabulary while learning to read, but the focus of the classroom is on learning the vocabulary as a part of the greater process of learning to read.

In science education, as seen from this perspective, there are two main activities: learning science and making science. Through the activities of learning and making science, the concepts, models and theories become meaningful. The learner is in the act of becoming a successful learner of science and the teacher is the model of how learning in science must be done. The particular concepts used in the classroom are secondary to the primary activity of understanding how science is learned in a particular classroom (White et al, 1995). However, the activities of learning and doing science seem to be hopelessly interwoven in the classroom (Songer & Linn, 1991). In the classroom in which the authors teach, the philosophy is that the way that science is done is also the way that science is learned or that students learn science by doing science. However, the reality of most learning situations is that the students know that there are already answers to the questions that they are involved in studying and in particular that the instructor knows the answers to these questions. Scientists answer questions that are unknown and they are not guided toward the answers by instructors as students are in a classroom. We would like our students to act as scientists, but other constraints insist that we act as guides.

It is evident that the goal of a science classroom is to learn science. However, it is not often made explicit how this learning is to occur. In the case of the grilled cheese sandwich, the teacher made the students aware of what was needed to make the sandwich. In the case of the science classrooms, we need to make students aware of what is needed to learn and do science. In our classroom, it is implicit in the classroom activities that students are expected to learn science through inquiry and problem solving as guided by the activities and by the instructors. However, we do not often make explicit to the student what we mean by learning or doing science. The student is expected to develop the abilities needed to do these activities without them ever being pointed out by the instructor or without the student possibly even being aware of them.

This study proposes to investigate the ZPD of preservice elementary education students with respect to the learning and doing of science. Since we can not measure the development of these skills directly, we will be measuring how students' beliefs about science learning and science making change as a precursor to these skills. Both authors teach a non-traditional science course in which students begin with certain beliefs which affect how they proceed in learning and doing science. Students then work together and with the instructor within their individual ZPD's. The goal of the instructor is to be a mentor and to provide tasks and scaffolding aimed at helping the students develop the notion of science making and learning as a meaning-making activity. It is hoped, then, that students will change their ideas as the course progresses. Also, in these science classrooms, science making and learning are presented interwovenly. That is, science is learned by doing. Students are involved in problem-solving activities designed to teach students particular concepts as well as involving them in the pursuit of science. For this reason, we are looking at differences between students' ideas of science as compared to their ideas of learning. Roth and Roychoudhury (1994) also studied student views about learning in a non-traditional physics course and found that students' views were often inconsistent. For this reason, we expect that there may be some difference.

METHOD

The study included 22 pre-service elementary education students enrolled in either a physical science or life science course at a mid-sized Midwestern university. Each class was taught by one of the authors for a fifteen week period. Both classes emphasize problem solving and inquiry-based activities as a means of teaching science. During the fifteen week semester, students participated in a guided reflection task. Every two weeks during the semester, the students were given two questions to which to respond and reflect. One of these questions inquired into the students' beliefs about how science is made. The other required students to reflect on their understanding of how science is learned. These journals were then collected at the end of the two week interval to allow feedback to instructors and students and returned at the next class meeting. Journals were graded on a check system which was determined based on the reflection that went into the journal and not on specific beliefs. Instructors' comments were limited to clarifying questions and not judgmental comments. There were a total of four entries in the science making category and six in the science learning category.

Two of the questions were adapted from Hewson and Hewson (1989) asking about the nature of science and the nature of learning.

After the course was completed, the journals were photocopied in order to be coded. Both researchers met to discuss a possible coding scheme for the data. The scheme shown in Table 1 was developed to describe a continuum of beliefs about science and science learning as a meaning-making activity from a passive view to a more active view. This continuum of active to passive can also be thought of as a continuum from a constructivist view to a positivist view. Also, the scheme can be mapped onto the static, mixed, and dynamic views in Songer and Linn's (1991) scheme. The difference is that we recognize a larger progression of views from static to dynamic knowledge. The most passive view of science considers science a body of knowledge or a set of facts and learning science is a matter of listening, reading, or memorizing those facts. A more active view considered science to be a matter of replicating the work of others. Learning in this view may be about asking questions, but that these questions may be found in books or in the work of others. A middle view between passive and active depicted science as existing in objects and that learning was a matter of manipulating these objects until their "science" becomes apparent to the learner. In the fourth view, experimentation is mentioned as a means of doing science, but no reasons are given for why the experiments were done. Similarly, learning in science involves experimentation, but that experimentation is not necessarily for the purposes of understanding. The fifth view is the most sophisticated in terms of viewing science and learning as a way of making sense of the world.

Table 1
Coding Scheme of Views of Science

Code	Science Learning	Science Making
1	Learn by listening, reading, or memorizing	Science is a body of knowledge
2	Learn by looking up questions in books or asking others	Science is replication of what others have done
3	Learn by working with objects	Science is in objects
4	Learn by doing experiments	Science is done by experimentation
5	Learn by trying to understand	Scientists try to understand phenomenon

Each question on science learning and science making was coded along this scale. Student answers that did not fit the scale or were absent were coded with an O, indicating an "other" response or that they did not complete the question.

The code for each subject's response to each question was recorded for each question. In the case that questions had multiple parts, each part was coded separately. These codes were divided into three separate tables. In the first one, the questions pertaining to learning were separated from questions pertaining to science. Next, the learning and science questions were separated by the time that they were presented to the class. Questions assigned and completed before the seventh week were classified into one group and those completed after were assigned to the second group.

RESULTS

There were three items of interest in this study. The first was to describe the students' views of science and science learning. Next, we are interested in comparing the views of science to the views of learning. Finally, we will compare the students' views of learning and science from the beginning of the course to the end to determine whether or not students' beliefs of science changed.

In response to the first question, the students' beliefs were well described by the coding scheme. Only 12% of the students' responses were not included in the coding scheme. Of these twelve percent, a portion can be accounted for as skipped responses. Tables 2 and 3 include example questions and responses from the data that were coded with each of the five codes.

Table 2

Views of Learning Science

Code 1: Learn by listening, reading, or memorizing

Q: Explain how you will go about studying for this upcoming test. Why are you using these strategies? If someone else were asking you for advice on how to study for this test, what would you tell them? Why?

Bio Student: *I am going to break each topic up and study for each one differently. For the genetics part, I've made notecards with each variation, phenotype and results on one side of the card and then on the other side I have stated whether the genetics variation was simple, codominance or sex linkage. After (that), I have memorized each notecard and wrote out each variation on paper until I got every single one right.*

Phys Student: *..I find it easier to learn definitions when I write them on notecards, then go over it and over it, till I know them.*

Table 2 - Cont.

Code 2: Learn by looking up questions in books or asking others

Q: Think back over what you remember about physical/life science when you were growing up....What about junior high or high school? What was physical science like? Did you like it? What did you learn about physical science?

Phys Student: *Chemistry was my favorite because I love numbers and playing with equations. I also liked learning about the periodic table.*

Code 3: Learn by working with objects

Q: Think back over what you remember about physical/life science when you were growing up....What about junior high or high school? What was physical science like? Did you like it? What did you learn about physical science?

Bio Student: *I remember learning about genetics and we had to use these little plastic pieces that looked like genes and we had to put them together like a puzzle.*

Phys Student: *I preferred biology because we learned about the body and we got to dissect animals ad observe the systems.*

Code 4: Learn by doing experiments

Q: Think back over what you remember about physical/life science when you were growing up, when you were in elementary or middle school. What was it like? What did you do? Did you like it? What did you learn about life/physical science?

Phys Student: *I remember in my math class we used a ball and dropped it to the floor. We tried to measure the height of the bounces. We also kept track of the number of bounces.*

Bio Student: *I did make an eggdrop box in 5th grade and we did some experiments. I did not do any "life science" things that I can remember.*

Table 2 - Cont.

Code 5: Learn by trying to understand

Q: Consider the following instance: A teacher in a middle school at the start of a unit on geology asking the class, "What can you tell me about the objects I've passed around the class?" Is there learning going on? Why? Why not? If you cannot tell, what else would you need to know in order to be able to tell?

Bio Student: *The reason the teacher (is) asking for a child's input on the objects discussed are as follows: The reason could be to find out the students' misconceptions about the object, also to learn their prior knowledge.*

Phys Student: *Yes, there is learning going on in this activity, because the student has to distinguish what the objects are, and explain what they are in detail. So yes, the student is learning because they have to think in order to learn.*

Table 3

Views of Doing Science

Code 1: Science is a body of knowledge

Q: Draw a physicist/biologist. Describe and explain your picture in detail!

Bio Student: *She would take the information and store it on a computer program in an orderly manner. She would also use the computer to write in additional thoughts and comments as well as updates to the data.*

Phys Student: *She uses the chalkboard to write fast facts the students should grasp. She also writes objectives that the students should be able to grasp within the school year.*

Table 3 - Cont.

Code 2: Science is replication of what others have done

Q: Consider the following instance: A student at home following a recipe for blueberry muffins. Is there science going on in this case? Why? Why not? If you cannot tell, what else would you need to know in order to be able to tell? How would this information help you?

Bio Student: *I don't think that there is any science going on and the only thing I can think of as a form of science would be mixing the ingredients. You can teach any recipe as a part of science.*

Phys Student: *Let's say the muffin is a scientific theory. Someone else designed the theory (muffin), and you have to follow the experiment (recipe) to reproduce the same results.*

Code 3: Science is in objects

Q: Consider the following instance: A student at home following a recipe for blueberry muffins. Is there science going on in this case? Why? Why not? If you cannot tell, what else would you need to know in order to be able to tell? How would this information help you?

Phys Student: *Science is also occurring in this instance because in order for the blueberry muffins to become muffins they must be heated. The heat will allow for the dough to rise and cook the muffins if the stove is set at the correct temperature.*

Phys Student: *..cooking in a way is science. Because you are mixing different elements together to come up with blueberry muffins.*

Code 4: Science is done by experimentation

Q: Draw a physicist/biologist. Describe and explain your picture in detail!

Bio Student: *This biologist just finished an experiment using his microscope.*

Phys Student: *The woman physicist is weighing how much a chemical weighs before and after boiling.*

Table 3 - Cont.

Code 5: Scientists try to understand phenomenon

Q: Draw a physicist/biologist. Describe and explain your picture in detail!

Phys Student: *She is thinking about friction because the cars' wheels do have an effect on how far the car will go.*
Bios Student: *...wanting to know exactly why and how something happens.*

In the next part of the study, student responses on questions about learning were compared to questions about science. Table 4 shows the mean score for views of science and views of learning by all the students and the results of a T-Test between those means. The T-Test was significant indicating that the student responses to the science questions were significantly less sophisticated than their responses to the learning questions.

Table 4
Science vs. Learning

	Views of Science	Views of Learning	T-Test Significance
Mean	2.13	3.30	0.005

Next, student responses to learning and science questions from the first half of the semester were compared to those from the second half of the semester. The mean scores for these questions are shown in Table 5. A T-Test was performed to compare the differences between the mean scores on each set of questions. The results of that test are also shown in Table 5. The difference between the scores on the science questions at the beginning of the semester were not significantly different from those at the end of the semester. However, there was a significant difference between the scores on the learning questions from the beginning of the semester to the end indicating that the codes used to evaluate the students' responses from the first half of the semester were lower than those used in the second half of the semester.

Table 5
First Half Views vs. Second Half Views

	First Half Mean	Second Half Mean	T-Test Significance
Views of Science	2.77	3.31	0.173
Views of Learning	2.39	3.06	0.006

DISCUSSION

The coding scheme developed by the researchers was successful in describing the views of science and science learning that students had in the physics and biology courses. This way of thinking about students' ideas of science and science learning was very helpful in understanding how students were thinking during the semester. The addition of more stages from the passive to active views of learning and doing science provided more detail into how the students' views were changing.

It was interesting that the students' views of science were different from the their views of learning and that these views of science did not change during the semester. It appears that many students began with a certain idea of how science was done and learned, but changed their idea about science learning only. Students were more easily able to adapt to the notion of science learning as a meaning-making activity than they were to science making. This difference is consistent with the findings by Roth and Roychoudhury (1994) and with Edmondson & Novak (1993), but may be at odds with results by Schommer & Walker (1995) who found that epistemological beliefs are domain independent. This result may have been due to the preservice teachers having had more experience in science learning than in doing science. Also, the students may have reflected more on how science is learned or taught in relation to education courses that they may have taken.

Students' ideas changed in a positive way throughout the semester in terms of science learning. This is only an exploratory result and a much more rigorous analysis of the instrument and a larger subject base is necessary to answer this question more fully. However, this result does indicate that further investigation into this question might provide interesting results.

The idea of students' fostering the notion of science making and science learning as a meaning-making enterprise is very important. This is especially true for the pre-service teachers participating in this study. One experience in a constructivist course does produce some effect, but students need more classes in the inquiry/problem-solving tradition with teacher mentors determined to foster that change. In addition, it is critical for instructors to be aware of students' development. We feel that the reflection book is an excellent tool towards that end. In the future we hope to track the students as they participate in more and more of these courses. Perhaps with time the students will emerge from their initial ZPD's.

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