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ABSTRACT

The goal of this study was to understand how preservice biology teachers progress in an open-inquiry research program on the ecological physiology of a tree frog. The project involved students (N=10) in a spring semester and summer workshop. Multiple data sources were established including classroom discussion, group meetings, weekly reflection essays, interview transcripts with students and the instructor, and instructor-produced artifacts. Six intensive cases are used to illustrate understanding of students' views of scientific research over time. Results indicate that most participants think of scientific research as a routine, cut-and-dried process, and they associate the nature of scientific knowledge with the process of deriving it. The participants concluded that the process is as objective and unambiguous as scientific results. Findings also suggest that experimental failure or blind alleys provide invaluable practice in essential laboratory skills and techniques. Contains 32 references. (DDR)

The authentic learning of science in preservice biology teachers in an open-inquiry research on tree frogs

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Abstract

The purpose of this study was to understand how preservice biology teachers progresses an open-inquiry research program on the ecological physiology of a tree frog (Chirixalus eiffingeri). The project involved 10 students in a spring semester and a summer workshop 1997. Multiple data sources were established including classroom discussion, group meeting, weekly reflection essays, interview transcripts with students and instructor, and instructor produced artifacts. We taped all laboratory discussion and took field notes during discussion and experiments. Six intensive cases were used to illustrate our understanding of students' view of scientific research over time. Our results showed that most participants think of scientific research as a routine, cut-and-dried process. They associated the nature of scientific knowledge with the process of deriving it and conclude that the process is as objective and unambiguous as scientific results. As the research goes on, they can't tolerate it that the reality is much different. We also found the experimental failure (blind alleys) did provide invaluable practice in essential laboratory skills and techniques. Intra-group and inter-group discussions were vital to the continuation and success of research project. The findings of this study have direct relevance to the planing and implementation of science courses in the Teacher Education Program.

Introduction

The introduction of inquiry-based science into school curriculum is important for the development of scientific skills of students (Schwab, 1963; Tamir & Lunetta, 1978, 1981). This inquiry-based curricula emphasize the development of inquiry skills: Students were supposed to act like scientists. According to Project 2061, the teaching of science should be consistent with the spirit and character of scientific inquiry "which suggests such approach as starting with questions about phenomena rather than with answers to be learned; engaging students actively in the use of hypothesis, the collection and use of evidence, and the design of investigations and processes; and placing a premium on students' curiosity and creativity" (American Association for the Advancement of Science, 1989, p.5). However, some studies have shown that inquiry based curricula have failed to promote inquiry related higher-level thinking skills-thinking critically, reasoning, solving problems-among students of school science (Shymansky & Kyle, 1992; Tobin & Gallagher, 1987).

Why has science education been unable to assist students in developing important inquiry related higher-level thinking skills? Burbules and Linn (1991) argued that the traditional science classroom provides an inaccurate representation of nature of science and of how scientific understanding is generated. Linn (1992) suggests that traditional science courses convince students that science is a collection of facts to memorized rather than a set of principles that are warranted by evidence. Hence, science teachers have been challenged to present science as authentic rather than a mythic, textbook subject. But the reality is too often teachers instructional approaches do not portray an authentic view of science (Martin et al., 1990).

Martin et al.(1990) suggest that in order to qualify science to be authentic, it needs to satisfy three conditions. Firstly, that the view is authentic if it arises from a primary or first hand experience of scientist. Science may also be considered authentic if it is in accord with a commonly held agreement over what constitutes science. Included could be agreement over methodologies, goals or meanings in science. Finally, a view of science may be considered to be authentic if it is a reliable or trustworthy or genuine representation of what science really is.

Martin et al. (1990) conclude that a science education that is tending toward authenticity would be one that draws in as many relevant aspects of science as are appropriate at a given point in the students' life. For the student this may imply that greater emphasis be placed on the development of an experimental bases (laboratory) rather than in the formal development of "scientific facts and ideas".

Laboratory activities have long been a distinctive and central role in the science curriculum and science educators have suggested that many benefits (for example, the authentic science) accrue from engaging students in science laboratory activities. Laboratory experiences have been purported to promote central science education goals including the enhancement of students:

1. understanding of scientific concepts;
2. scientific practical skills and problem solving abilities;
3. interest and motivation;
4. understanding of the nature of science (Lunetta, 1997)

Experimenting was made as the core of the science learning experience in the 1960s and 1970s (Shulman and Tamir, 1973). However, laboratory instruction has failed to enhance meaningful learning (Tamir, 1989). Tobin (1990) suggests two distinct shortcomings regarding the laboratory experience, first, current science teaching rests on an inappropriate epistemology; second, collaborative methods are not used in science laboratories.

Typically, primary focus of laboratories is to verify the established laws and principles, or to discover objectively knowable facts (Tobin, 1990). In these laboratories, students follow the "cook book" (laboratory manual), gathered data without comprehensing the meaning of their actions. The cognitive demand of laboratory task was reduced to a minimal level and without reflective thought. Traditional laboratory incorporated minimal scope for students to connect their personal experiences to develop scientific principles. It is not surprising that it often to provide an inappropriate learning environment.

An open-ended inquiry was suggested by numerous studies to replace "cook book"(or recipe) laboratory activity in order to enhance authentic science learning (Biddulph and Osborme,1984; Roth, 1995) . Rithchie and Rigano (1996) reported high school students working in a chemical engineering laboratory in a university under the mentorship of a scientist. Garofalo (1992) reported high school teachers participating in a research in a physics laboratory. However, these studies have focused on the open-inquiry in the secondary school levels, little is known about at the level of college training for preservice teachers..

The principal purpose of the present study was to document the intellectual thinking of preservice biology teachers during an open-inquiry while participating an ecological physiology research.. Specifically, we investigated how and why students engaged in a learning through an open-ended laboratory research project in a scientifically authentic context.

Research Design

Context of the study

A total of 10 students took part in an independent study course in the spring semester 1997. This course was distinctive when compared to a traditional courses in that it emphasized the open-inquiry character of students. Student were divided into three groups to conduct a research projects on the ecological physiology of a tree frog, Chirixalus eiffingeri.

The reproductive mode of C. eiffingeri(Family, Rhacophoridae) is very unique in several aspects. Of the 32 species found in Taiwan, C. eiffingeri is the only species that use arboreal aquatic micro-habitats that occur in tree holes or bamboo stumps for breeding purposes (Kam et al., 1996). These arboreal aquatic micro-habitats are isolated, small water-bodied pools that have low dissolved oxygen and primary productivity. During the breeding season (February to August), female frogs lay fertilized eggs above the water line on the inner walls of bamboo stumps. After that, a male frog stays in the bamboo hole to guard the embryos until they hatch 10-14 days later. Upon hatching, tadpoles drop into the water pool where they grow and develop and metamorphose about 2 month later. C. eiffingeri tadpoles are oophagous which is one of the most fascinating adaptation probably in response to food scarcity in water pools. The unfertilized, trophic eggs are laid by female frog who revisit her nests at an interval of about 8 days during the tadpole period.

Method

Our study was designed to be interpretive (Erickson,1986). In the sense that, the actions taken by participants within an educational setting were investigated to understand from the perspective of the participants (Tobin,1995). We wrote reflection essays based on documentary records such as structured and unstructured interview transcripts, group meeting, class discussion, and experiment events to identify the significance of actions in the events from various points of view. All laboratory discussion were taped and observed by taking field notes which focused on the context, discursive interaction within group members and their actions contexts in which students talked about the experiments.

The analysis processes consisted of reviewing and comparing the data sources and doing in depth understanding of the participants. As the data were analyzed, we generated tentative assertions that addressing the research question (Erickson 1986). Additional data were collected to test the assertions and all data were classified as supporting or refuting each assertion.

The extended field observation over a 6-month period provided an opportunity for us to observe typical laboratory behavior of students and instructor and to establish rapport and build the trust necessary to acquire understanding and making interpretation the contextual meanings of students actions. Member checks (Guba and Lincoln, 1989) provided the students and instructor with the opportunity to improve the authenticity of the results by confirming or suggesting alternative interpretations.

All developing assertions and data were given to the participant and the teacher at monthly bases for comment. Since the study followed a hermeneutic cycle where the assertions developed in a continuous cycle of data gathering analysis and interpretation.

The questionnaire used in the study was initially generated by the researcher and the supervisor of the course. We were keen to find out what the participants' view on a scientific research. Subsequently, the questionnaire was administered to all the participants in the study. Although the questionnaire was open-ended, it provided the participants the opportunity to express their ideas and concerns in relation the their studies. The questions asked were as followed:

1. Briefly, what is science?
2. Why do you take this course?
3. What do you know about scientific research before taking this course?
4. What do you know about scientific research now?
5. Do you think that you were taught differently this time compared to the laboratory that were taught in the past?
   (a) If so, how?
   (b) Was it better? Why?
6. Do you like group work? Explain.
7. What kinds of problems you have encountered during the research? Who has solved the problem and how?
8. Do you have any comment to add?

Questions 1-3 were intended to focus participants' thoughts on past laboratory experience and allow reflection of the procedure and content covered. Most participants have not previously experience an open-ended laboratory experience and questions. Question 4-5 was designed to allow participants to compare the current approach to their traditional laboratory experiences of the past. Question 6 was included because the open-ended approach required an emphasis on small group discussion and direct participants interactions. Question 7 was designed to find out the kinds of problem participants have faced and how did they solved them. Finally, question 8 provided students with an opportunity to comment on any other issues in relation to the study.

In the following section, the results from the questionnaires and the interviews are presented. The responses have been used to generate a number of assertions about participants perception of the open-ended laboratory.

Results and Discussion

1. The subject content of the project should be interesting enough in order to motivate students to do the project. The following interview excerpts illustrate this:

> "Well, the reason that I take this course is because this particular tree frog is very fascinating, and I'm very eager to know more about its breeding biology" Ya 1/12

> "As I heard the seminar about the tree frog given by the professor six months ago, I was impressed by the remarkable feeding behavior of the tree frog. I can't believe that the female frog feeds her tadpoles by laying unfertilized eggs in to the water pool." Hw 2/9

2. All perspective teachers recognized the need for working collaboratively throughout the project. Intra- and inter-group discussions were vital to the continuation and success of research project. The perspective teachers indicated in their questionnaire responses that they enjoyed the cooperative approach because they were able to express their own ideas regarding the decision making when the research comes to a critical point. Some participant, for example, stated:

> "Without the group discussion, I don't think that I can finish this project. Because this is an open-ended project, even the supervisor does not know what to expect regarding the results of the project; thus, the group discussion not only plays a vital role in guarding us during the study, but also serves as supporting group to encourage and motivate each other when things go wrong. Ch 9/7

> "Cooperation was a lot better and far more creative method in such an open-ended research project. It motivated, in some case, 'forced' everyone involved in the process of experiment. We met weekly and discussed the problems that we faced and, often, arrived a consensus

ourselves. This process made me think, question, and respect other's opinions. Ch 3/15

"I felt really good about myself when the team accepted my ideas to improve the research protocol. This means a lots to me because I must have done it right and the teammates have taken my suggestions seriously"
Ch 9/10

3. **Most participants think of scientific research as a routine, cut and dried process.** Before taking the course, most participants associated the nature of scientific knowledge with the process of deriving it and conclude that the research is as objective and unambiguous as scientific results. As the research goes on, they can't tolerate it that the reality is much different.

Participants were asked to describe how they would normally prepare for a research (doing just like scientists were normally do) prior to being involved in the topic they had just decided, i.e., the research project upon which both participants and the supervisor have agreed. Nearly all responses were centered around the scientific research was a routine, cut and dried process. At the end of semester when asked to describe what they thought about the research they had done, nearly all participants finally realized that the nature of the science research was very different from that of the traditional laboratory experiments in that the former demanded more time and effort than they expected to repeat the experimental trials (replications), and to modify the experimental protocols in order to make it work. The responses are typified by the following comments:

"I didn't expect to invest that much of time to deal with the oxygen analyzer. Initially, I thought all I needed to do was to put the tadpoles into the metabolic chamber (i.e., a 60 mL syringe) for a duration of time, injected the water sample into the oxygen analyzer, and the machine then gave me the readings. In reality, I had spent endless of time just to make a right metabolic chamber for a small-sized animal like tadpoles. In addition, to get the recorder and the oxygen analyzer to work consistently also took up tremendous amount of time." (Ya 7/9)

4. **The experimental failure, also referred to as blind alleys by Roth (1994), provides an invaluable practice in developing the skill for problem solving.** Students were often frustrated by the experimental failures, and they were unable to realize the fact the experimental failure happened more often than success in the process of an open-ended experiment, and experimental failure often played a key role to 'force' participants to think and solve problems.

Hodson (1993) advocated giving the students the sort of on-the-job training. Our results showed that the experimental failure did provide the opportunity for students to be trained in many ways. Because all projects are open-ended, and the projects have never been done in the laboratory, the supervisor and participants at first figured out the general protocols for the experiments, and often the supervisor showed them how to operate an instrument, if needed. The participants then needed to have their experimental protocols worked out and presented to the supervisor and the other group members. As the experiments went on, different kinds of problems keep emerging. During the inter-group meeting, the supervisor and the participants often spent a lot of time to figure out a way to solve the problem. Participants were more willing to express their views and comments since they realized that the supervisor did not have the 'right' answer for the particular problem. Often participants proposed different methods, and they tried the proposed methods with enthusiasm after the discussion session. Throughout the study period, participants, in a sense, were 'forced' to think, reason, and discuss. In contrast, in a traditional laboratory experiment, participants never have the opportunity being 'forced' to think and reason since they were instructed to follow an experimental protocol given by the instructor. In addition, even when they failed the experiment, they could easily find out the solution for the problem from the other group that next to them.

Conclusion

In 1988, Chiung-Fen Yen, a 32-year-old graduate student in the department of Wildlife Ecology at Iowa State University, was working early on an data analysis regarding an experiment investigating the variation in nesting success of the American Robin (Turdus migratorius)(Yen et. al. 1996). For months Yen had used the May field method to calculate daily nest survival rates (May field 1975, Johnson 1979) with the help from a statistician Steve Ruthbun. For some unknown reason, Yen hadn't been able to get the reasonable value that could explain the phenomenon which she observed from Robins. But that morning she redo it again and the result came out great, that means it could explain the variation in Nesting success of the Robin!

In a state of delirious excitement, Yen raced through the stairs of the Science II building looking for someone with whom she could shared her joy. Moments of scientific discovery can be among the most exhilarating of a scientist's life. The desire to observe or understand what no one has ever observed or understood before is one of the forces that keep researchers rooted to their laboratory benches, climbing through the dense undergrowth of a sweltering jungle to check the bird nest, or pursuing the threads of a difficult theoretical problem. Few discoveries seem to come in a flash; most materialize more slowly over weeks or years. Nevertheless, the process can bring great satisfaction. The pieces fit into place. The whole makes sense.

However, a life in science can entail great frustrations and disappointments as well as satisfactions. An experiment can fail because of a technical complication or the sheer intractability of nature. A great hypothesis that has consumed months of effort can turn out to be incorrect. How is the limited fallible work of individual preservice biology teacher finish an experiment converted into the enduring edifice of scientific knowledge?

Scientific inquiry in the science laboratory is a cognitively complex process which requires the students' involvement (Tobin, 1986), background experience and knowledge (Klahr et al., 1993), metacognitive activity and cognitive processing (Kuhn et al., 1988), and adequate comprehension and communication skills (Baxter et al., 1992). This process may be facilitated by knowledge and experience with the basic and integrated science process skills (Germann, 1989; Tobin, 1986). Science educator's challenge is to find ways to support student efforts during inquiry experiences.

We believe that the preservice teachers' participation in the Independent Study course will lead to an enhancement of their knowledge base for teaching. They came away from the experience with new knowledge about the structures, the applications, and the teaching of biology and the laboratory. This course benefits him in a way that traditional biology laboratory could not. Through the Independent Study course, the preservice biology teachers were engaged in contemporary research practice, and they were exposed to contemporary ideas, questions, and applications in a first hand way. In short, in a very real sense, they became part of the biological research community, e.g., present their research results in the Animal Behavior and Ecology Symposium. This experience led to an increase, not only in his knowledge base, but also in his enthusiasm for biology and its teaching.

> "I told my students about the research experience, and they seemed impressed ....and they seemed to be more engaged in the class than before.............." (Wu 2/34)

This initial field trial is significant because it has given us confidence that such an experience can be both accessible and valuable to perspective teachers. Furthermore, it has given us some ideas for developing a research experience for in service teachers program specially for biology teachers who is interested in ecological physiology field. The findings of this study have direct relevance to the planing and implementation of science courses in the Teacher Education Program. We promote that the open-inquiry research experience is necessary in the Teachers Education Program.

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