استخدام طريقة تعليمية تأملية-صريحة خلال منهج تعليمي مبني على استخدام التكنولوجيا لتعزيز استيعاب الطلاب لطبيعة العلم

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الملخص:

هدفت هذه الدراسة إلى معرفة مدى تأثير استخدام طريقة تعليمية تأملية وصريحة خلال منهج تعليمي مبني على استخدام التكنولوجيا لتعزيز فهم الطلاب لطبيعة العلم. وذلك في سياق مقرر علم الاحياء. هذا و قد ركزت الدراسة على عناصر طبيعة العلم التالية: أهمية الاساس التجريبي للمعرفة العلمية، التغير وعدم الثبات للمعرفة العلمية، و الإبداع الإنساني في الوصول للمعرفة العلمية. وتمثلت التكنولوجيا المستخدمة في الدراسة في برنامج"صراع البقاء" والذي يستخدم بيانات تمثيلية (غير حقيقية) عن عصافير جزيرة جالاباغوس. واستخدمت الدراسة الطريقة التأملية الصريحة في التدخل البحثي. بلغ عدد الطلاب المشاركون في هذه الدراسة الاستطلاعية حوالي ٣٣٠. و اختيرت عينة عشوائية تتكون من ١١٦ طالب و طالبة، ٥٦ من الذكور و ٦٠ من الإناث. واستخدمت بعض فقرات استبانة "استطلاع الأراء حول طبيعة العلم-الاستمارة ج" إلى جانب مقابلات شبة مقننة (ذات طابع حواري مفتوح) من اجل تقييم اراء الطلاب حول طبيعة العلم قبل و بعد الانتهاء من التدخل. و توصلت الدراسة إلى أن معظم الطلاب كانت لهم أراء غير مطّلعة حول عناصر طبيعة العلم المستهدفة، قبل التدخل لبحثي. اما بعد نهاية الدراسة فقد تطورّت أراء الطلاب حول تلك العناصر لتصبح أكثر إطلاعا. و دلت نتائج الدراسة على أن استخدام طريقة تأملية و صريحة مقرونة بمنهج تكنولوجي الاساس يؤدي إلى تطوير فهم الطلاب لطبيعة العلم.

A reflective-explicit instructional approach during a technology-based Curriculum to enhance students' understanding of the Nature of Science

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Abstract

This study examined the effect of a reflective-explicit instructional approach during a technology-based curriculum on the understanding of the nature of science (NOS) within an introductory college biology course. The study emphasized the tentative, empirical, creative and imaginative aspects of the NOS. The technology utilized in the study was the *Struggle for Survival* program that uses a simulated data based upon the finch population on the Galapagos Island Daphne Major. A reflective-explicit instruction of the target NOS aspects served as the intervention. The randomly selected sample of the study included 112 students, 54 male and 58 female. Selected items of the Views of Nature of Science Questionnaire-C (VNOS-C) in combination with semi-structured interviews were used to evaluate students' NOS views before and at the completion of the intervention. Before the intervention, the majority of students held naïve views of the target NOS aspects. At the end of study, students demonstrated more articulate informed views of the target NOS aspects. The results of this study indicated that a reflective-explicit instructional approach coupled with a technology-based curriculum had a positive effect on the understanding of the NOS aspects.

Introduction

Science education reforms call for building a scientifically literate society. This education is vital in order to train people on how to deal with global problems such as population growth, destruction of tropical forests, extinction of plants' and animals' species, scarce natural resources, and nuclear war (AAAS, 1990, 1993; NRC, 1996).

Current science reform efforts emphasize the importance of developing an understanding of NOS and scientific inquiry among students of all educational levels (AAAS, 1990, 1993; NRC, 1996). The goal of these efforts is to create scientific literacy. Scientifically literacy is usually viewed as capacity to develop and make educated decisions in the areas of science and technology. Another vital goal is the thorough understanding of scientific concepts, the process of science and the NOS. To produce a scientifically literate society, schools must equip students with an education that encourages a deep understanding of the nature of science, mathematics, and technology, and how these subjects operate both independently and together (AAAS, 1990, 1993; NRC, 1996).

While there is still a debate concerning both the definition and best strategies to facilitate students' understanding of the NOS, there is a general consensus among science educators that particular aspects of the nature of science should be incorporated into the science instruction (Lederman & Abd-El-Khalick, 1998; Schwartz et al., 2001). These characteristics regarding the nature of science consist of (1) scientific knowledge has a tentative character, (2) scientific knowledge is based on empirical evidence, (3) scientific theories and laws serve different roles in science, thus theories do not become laws with further evidence, (4) scientific knowledge relies profoundly, but not entirely, on observations and inferences, (5) scientific knowledge is derived from human reasoning and imagination, (6) scientific knowledge is influenced by society and culture, and (7) scientific knowledge is heavily subjective and based on interpretation (Lederman et al., 2001).

There is a general agreement among researchers and science educators that teachers and students do not posses an adequate understanding of aspects of the nature of science. Despite the many attempts to improve this understanding, little success has been realized (Abd-El-Khalick & Lederman, 2000; Lederman & O'Malley, 1990; Gallagher, 1991; Meichtry, 1992; Matthews, 1994). The latest studies suggest that in order to help students enhance their conceptions of the NOS, a reflective and explicit approach should be used. This approach needs to provide students with opportunities to explicitly discuss and reflect on the aspects of the nature of science and will result in a better understanding of what science is, how it works and how scientists go about doing their work (Bell, 2001).

Approaches for Learning the NOS

Several approaches have been developed since early 1950s to assist students improve their understanding of the NOS (Lederman, 1992). Most of these attempts incorporated the implicit approach. This approach emphasizes that students will come to improve their understanding of the NOS simply by the engagement in science-based inquiry activities or science skills teaching (Lederman, 1992; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Lawson, 1982).

Many researchers though including (Abd-El-Khalick & Lederman, 2000; Lederman, 1992; Schwartz & Lederman, 2002; Metz, 2003; Kenyon & Chiappetta, 2003) resolved that the implicit approach did not help students improve their understanding of the NOS. This conclusion motivated some researchers to look for another approach that could assist students in developing the much needed understanding of the NOS.

The literature is rich with evidence that the explicit approach has the potential to assist students develop better understanding of the NOS (Southeland et al., 2003). Supporters of this approach (e.g., Durkee, 1974; Scharmann et al., 2003; Bell et al., 2002; Abd-El-Khalick & Lederman, 2000; Dass, 2001) argue that in order to improve students' understanding of the NOS, science learning should be instructed explicitly, the aspects of the NOS should be taught with or within a specific existing scientific content, and science instruction should be geared toward specific aspects of the NOS.

Technology is another theme consistently stated in recent science reform documents. It has appeared in the national science standards and is a central component in the development of scientific literacy (AAAS, 1990, 1993; NRC, 1996). Several critics of education envision technology as a significant tool that has the potential to meet current reform efforts (Means et al., 1993). By including technology education in the curriculum and utilizing technology to encourage learning, students are more likely to become aware of the nature, capabilities, and drawbacks of technology. Furthermore, by designing science projects that incorporate technology, students can become involved in problem-solving regarding a broad spectrum of real-world contexts (AAAS, 1993).

Definitions of the Study

(NOS):

The nature of science refers to the "epistemology of science, science as a way of knowing, or the values and beliefs of scientific knowledge and its development" (Lederman, 1992, p. 331).

The Implicit Approach:

The advocates of this approach support the sue of hands-on inquiry-based activities and science process skills instruction (Lawson, 1982; Rowe, 1974; Gabel, Ruba, & Franz, 1977; Haukoos & Penick, 1985). The implicit approach suggests students will come to develop an informed understanding of the NOS merely by "doing" science (Lederman, 1992; Abd-El-Khalick & Lederman, 2000).

The Explicit Approach:

The approach argues that students develop informed understandings of the NOS through explicit instruction primarily aimed at different aspects of the NOS (Khishfe & Abd-El-Khalick, 2002; Billeh & Hassan, 1975).

The Tentative Nature of Scientific Knowledge:
Scientific knowledge is never absolute. It is subject to change if new observations challenge current theories (Lederman et al, 2002; AAAS, 1990, 1993; NRC, 1996).

The Empirical Nature of Scientific Knowledge:
Scientific knowledge is based on empirical evidence (Schwartz et al., 2001).

The Creative and Imaginative Nature of the Scientific Knowledge:
Scientific knowledge is derived from human reasoning and imagination (Lederman et al., 2001).

Purpose of the Study

This study aims to examine the effect of a reflective-explicit instructional approach during a technology-based curriculum on college students' understanding of the NOS within an introductory biology course. The effectiveness of the reflective-explicit instructional approach on students' understanding of the NOS was measured in terms of individual views of the empirical, tentative, and creativity and imagination of the NOS. The following research questions directed this study: (1) What kind of views do students enrolled in an introductory science course have regarding the tentative, empirical and creative and imaginative aspects of the NOS, and (2) Do students' views change as a result of the reflective-explicit instructional approach during a technology-based curriculum?

Research Design and Instrumentation

A case study research design was used to evaluate the effectiveness of reflective-explicit instructional approach during a technology-based approach on college students' understandings of the NOS and in doing so employed the

Struggle for Survival program as a simulated tool which could facilitate such understanding. The study used selected items that were related to the aspects of the NOS from Views of Nature of Science Questionnaire-C (VNOS-C) (Lederman et al., 2001) as an instrument to evaluate students' understanding of the NOS. The pretest and posttest consisted of selected open-ended questions concerning the target aspects of the NOS. The questions on the VNOS-C were scored using a rubric modified by the investigator from Lederman et al (2002).

In addition to the VNOS-C questionnaire (Appendix 1), individual interviews were used to assess students understanding of the target NOS aspects. These interviews intended to validate the NOS questionnaire and summarize students' conceptions.

Participants and Procedures

Fourteen introductory biology course sections were selected for this study, which took place in fall 2003. The sample of the study was comprised of 116 students, 56 male and 60 female. The questionnaire was administered to all students at the beginning of the semester. Next, a sample of 8 students (4 male and 4 female) was randomly selected for individual interviews. Then the intervention was delivered to all the students. Following the intervention, the same questionnaire was administered to the entire sample. This was followed by individual interviews with a sample of 8 students (4 male and 4 female). The post-intervention group of students was different from those selected for the pre-intervention interviews. The students completed the NOS questionnaire in about 20 minutes under the supervision of the course instructor and the investigator.

To control for the teaching assistants' (TAs') views of the NOS, as well as their teaching experiences, the VNOS-C questionnaire was administered to the TAs prior to the intervention delivery. The investigator coded and assessed the TAs' views of the NOS and, as a result, designed a lesson plan and post activity discussion questions, geared toward the target aspects of the NOS, that served as the intervention. Students worked on the *Struggle for Survival* program for four weeks. Each of the fourteen sections met for three hours per week. In the first week and for 20-minutes, the tentative NOS was delivered to each section after they half-way completed an activity on the program that had an implicit connection to the tentative NOS. Students then continued with the activity. In this way, students had time to reflect on the explicit discussion of the target aspect of NOS. The delivery of the other NOS aspects took place on the next three weeks and followed exactly the same format. The investigator observed the delivery of the intervention to ensure that the TAs followed the outlines.

Intervention

Seven graduate teaching assistants (TAs) delivered the intervention to the students. They were all regular TAs for the 14 lab sections of the Biological Principles II course. Three of the TAs were female and four were male. They were all biology major and their prior teaching experience and background in nature of science or philosophy of science varied. To overcome this variation and to ensure consistency of the intervention, the investigator designed a lesson plan and the post activity discussion questions for the TAs (appendix 2). The lesson plan was compatible with the activities of the technology used in the study.

The intervention was to adhere to the following criteria: first, the teaching of the target aspects of the NOS includes the provision of opportunities for students to analyze the finch activities from different perspectives, such as the NOS framework, and to draw an association between their activities and the work of others, just as scientists do. This was accomplished through discussions associated with the finch activities. Secondly, the instruction of the target aspects of NOS is embedded in specific science content (the theory of evolution and the Galapagos Finches). This provoked the students to reflect upon their personal understanding and views of NOS as they relate to the activities. Finally, students were engaged in inquiry-based activities in conjunction with discussion about various aspects of the NOS. This discussion encouraged students to reflect on their experiences from within a conceptual framework to clarify certain aspects of the NOS.

The software interface allows students to arrange questions they are investigating and the explanations they are developing to solve each question. For example, students are prompted to develop explanations to answer "Why are so many of the finches dying?" and "Why are some of the finches surviving?" Those two driving questions are the theoretical framework through which students are to develop their explanations.

Struggle for Survival is an inquiry-oriented program, which includes many activities that correspond implicitly with the tentative, empirical, and creative and imaginative aspects of the NOS. For example, in one of the activities, students are encouraged to share their already formed hypotheses about the driving questions with their classmate via email discussion. Then they are required to re-investigate the data to gather the information necessary to distinguish between alternative hypotheses and find one which is best supported by the data. This activity corresponds with the tentative NOS. In their quest to complete this task, students should find that the data supports only one hypothesis. Other hypotheses that are not supported by the data are refuted. This signifies that scientific knowledge—in this case, hypotheses—is subject to change. The same activity corresponds implicitly with the empirical nature of the scientific knowledge as students should realize this through their attempts to eliminate the hypotheses that are not supported by data. This suggests that science is based on evidence and this separates it from other disciplines.

Another activity suggests to students that data (in the form of measurements) can be organized into a more understandable and condensed form. The activity then requires students to represent their already gathered data by creating various types of graphs. This activity implicitly proposes that scientists use their creativity and imagination when performing investigations.

The Technology

Struggle for Survival is a type of computer-based environment that is part of the Biology Guided Inquiry Learning Environment, Galapagos Finches Software. The software revolves around the studies of the finch population on the Galapagos Island Daphne Major (Grant, 1986). Using a resource of a rich database, students can apply the theory of natural selection to make observations of animals, such as weight, beak size, seed rigidity, eating habits, and mating behavior as well as understanding the local plant life and climate. The program allows students to observe real-life phenomena and as a result form their own explanations of why some finches survived while others did not (Tabak et al., 1996). As students study these characteristics of the fiches, they are required to form hypotheses and alternative hypotheses of why some finches died while others survived. Then students are asked to communicate their findings to their peers (Reiser et al., 200١).

In essence, the software is implicit in nature. The investigator developed and tutored seven TAs to deliver an explicit lesson plan containing several questions and charts as to how and when the discussion about the target NOS aspects should be incorporated in the activity.

Data Analysis

The investigator conducted the analysis on a pretest and posttest and therefore categorized students' responses of the target NOS aspects into three categories. If a student's response to a specific aspect was consistent with the scientific community's explanation and interpretation of that particular aspect (Appendix 3) then the student's response would be categorized as being informed. If the response was not consistent with the scientific community's explanation and interpretation, the student's response would be categorized as being naive. If the question that corresponded to a particular aspect of NOS was left unanswered or the student's answer was not clear, then that particular response was not categorized. This categorization scheme is similar to that found throughout the literature (e.g., Khishfe & Abd-El-Khalick, 2002; Akerson et al,. 2000; Abd-El-Khalick & Lederman, 2000). Discrepancies in percentages between pre and post tests were compared to evaluate students' gain or loss in each aspect of the NOS.

In addition, the investigator conducted the analysis of the follow up interviews. If for some reason there ware discrepancies between students' written responses and the interview's responses, the investigator would consider the students' responses of the interview.

Results

Students' pre-intervention views of the NOS

Research Question one RQ1: (1) What kind of views do students enrolled in an introductory science course have regarding the tentative, empirical and creative and imaginative aspects of the NOS?

Analysis of pre-intervention questionnaires concerning the target NOS aspects revealed that students held a generally naïve understanding of the NOS, particularly in the aspects concerning the empirical and creativity and imagination scoring, 79%, 47%, respectively. The results however, showed that students held a relatively informed understanding of the tentative aspect of NOS, scoring 50%. This is primarily due to the fact that most of the students included in the study have a scientific background and have conducted some scientific experimentation and investigation. Table 1 presents a summary of these results.

Table 1. Percentages of pre- and post-intervention informed and naïve views of target NOS.

Group	Tentative NOS		Empirical NOS		Creativity & Imagination NOS	
	Pre	Post	Pre	Post	Pre	Post
Informed	50	67	0	7	20	27
Naive	36	20	79	86	47	40
Not categorized	14	13	21	7	33	33

Fifty-percent of students reported either naïve or not categorized views regarding the target aspects of the NOS. For example, in reference to the tentative aspect of NOS, several students revealed a common misconception that theories can change but laws cannot. One student reported this misconception in the response, "Theories are not certain so they do change. Laws such as gravity do not change" (pre-interview). They also expressed that scientific knowledge does not change. One student wrote, "Scientific knowledge will not change because theories and laws have undergone years of scientific testing, and have called such theories and laws because the results of these tests have been consistent" (pre-interview).

Similarly, students reported misconceptions in reference to the creativity and imagination and empirical aspects of the NOS. Many students stated that the scientists used their creativity and imagination in their investigations, only in the planning and design stages and not throughout the investigation process. Likewise, when asked about the empirical aspect of the NOS, students expressed a very common misconception that science was the study of nature and can provide explanation for everything as one student acknowledged, "Science is different from other disciplines because it provides explanation for everything that happens in nature because science is the study of facts" (pre-interview).

Students' post intervention views of the NOS

Research Question Two RQ2: Do students' views change as a result of the reflective-explicit instructional approach during a technology-based curriculum?

Post-intervention questionnaire showed some improvement in students' views regarding the target NOS aspects. The students' scores that showed the most improvement in the aspect regarding tentative. The score jumped 17% in the tentative NOS from pre-intervention questionnaire (table 1). The aspects concerning the empirical basis of the scientific knowledge and creative and imaginative of the NOS changed by 7%. This was most likely attributed to the fact that most students had some difficulties understanding the meaning of the questionnaire related to these aspects, as realized by the investigator during the interviews. Improvement in the views was yet present between pre and post intervention in these two aspects of the NOS.

Post intervention interviews also showed more informed views regarding the target NOS aspects with the exception of empirical NOS. Concerning the tentative NOS, students came to realize that scientific knowledge is tentative and subject to change and that scientific knowledge is never absolute. One student affirmed, "Theories and laws are constantly changing because we are constantly studying new things" (post-interview). Another student added, "Scientific knowledge is always changing. Research is continuous" (post-interview).

In reference to the creativity and imagination NOS, students came to recognize the critical role of creativity and imagination in the development of scientific knowledge and that creativity and imagination is used throughout the process of investigation not just in the planning and design stages as most students thought in pre-intervention as one student pointed out, "It is very important for scientists to use their creativity and imagination when performing experiments and investigations. I believe that scientists should use creativity and imagination in all stages of the investigations" (post-interview). Another students added, "I don't think that scientists would have been able to arrive at their conclusions if it was not for using their creativity and imagination just like Newton" (post-interview).

Interestingly, when asked about what triggered changes in their views regarding target aspects of NOS, students were unable to recognize a specific learning event that caused the change. Many attributed the change to simply having more time to think about the question the second time around. However, on further probing during the interviews, students were able to identify some specific experiences or events that led to change in views between pre- and post-questionnaires. For instance, the researcher asked, "What may have triggered the changes in views between the pre- and post-questionnaire?" A typical response was "I guess seeing the question again, I thought about it more the second time". The researcher would ask again, "Was it some experience or event that happened during the course?" To this prompt a typical response was "We spent less time doing the pre-questionnaire because we had quizzes at the beginning of the year." The researcher would direct the response even further by asking, "Do you think the course or lab had anything to do with your change of view; if yes, would you be specific?" Some students cited the Galapagos Finch activity as an impetus for change, as one student responded:

You know how the finches…the weather patterns changed which caused the seed… only certain seeds could survive and all the finches could not eat every seed, only finches with certain beaks could eat certain types of seeds…(post-questionnaire).

In regard to the tentative nature of scientific knowledge, a second student attributed the change in views between pre- and post-questionnaire responses merely to the Galapagos Finch activity.

[I attribute] the Galapagos Fiches totally for [my change of view], just because we were to come up with our own hypotheses and it showed us that data does not necessarily say…it doesn't confirm one thing or another thing. It can go either way. But there are things that support and things that refute (post-questionnaire).

Discussion and Implications

The results of this study are consistent with those from previous studies that evaluated students' views of NOS (e.g., Abd-El-Khalick & Lederman, 2000; Kenyon & Chiapetta, 2003; Schaarmann, 1990). The results also indicate that a technology-based approach coupled with an explicit instruction of NOS were useful in helping students enhance their understanding of the NOS. The primary goal of the recent science education reform movement is to generate a scientifically literate society. The nature of science and technology are the main components of this literate society. This pilot study proved that teaching the nature of science explicitly and within a specific context is an effective method to improve students' views regarding the NOS.

Struggle for Survival provided students with the opportunity to study and reflect on real life data set. In conjunction with reflective-explicit instruction of the NOS aspects, technology provides a solid resource that can be used in improving students' understanding of the nature of science.

The study suggests some implications that include; firstly, the study emphasized only three aspects of the NOS, therefore the study offers a future implication for science educators and science teachers to teach additional NOS aspects in a similar approach in order to assess its effectiveness. Secondly, the results of the study were limited only to students who were enrolled in an introductory biology course. The NOS views of this student population are not representative of any other population. Thus, more studies that use the reflective-explicit instruction of the NOS with different populations are desired to establish the validity of the results of the study. Thirdly, the interviews' results of this study indicate that some students attributed changes in their views of the NOS aspects to *Struggle for Survival program.* Therefore, further investigations oh how technology may have the potential to help students enhance their views of the NOS are needed.

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Appendix 1: VNOS Questionnaire (Form C)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?
2. What is an experiment?
3. Does the development of scientific knowledge **require** experiments?

- If yes, explain why. Give an example to defend your position.
- If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?
5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.
6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?

- If you believe that scientific theories do not change, explain why. Defend your answer with examples.
- If you believe that scientific theories do change:
  (a) Explain why theories change?
  (b) Explain why we bother to learn scientific theories. Defend your answer with examples

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

- If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
- If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses 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 hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?
10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

- If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.
- If you believe that science is universal, explain why and how. Defend your answer with examples.

Appendix 2: Explicit lesson plan and post activity discussions

Galapagos Finches Unit

Objectives:

- Students will be able to discuss and understand some aspects of the nature of science, such as tentativeness, empirical nature of scientific knowledge and creativity and imagination used in the developing the scientific knowledge.
- Students will be able to relate the Galapagos Finch activities to aspects of the nature of science.
- Students will be exposed to the explicit/reflective approach of teaching the nature of science.

Procedures:

- The TA introduces the primary objective of the finch activities: "It is your job to determine what happened to the finch population by forming hypotheses and using relevant data to support these hypotheses.

- Students do Activity # 1
- The TA then asks students the following finch-related questions from Activity #1:
    - "What event or series of events led to the sharp decline in the finch population?"
    - "What factors attributed to the survival of some finches as opposed to others?"
- The TA poses these more general questions relating to science:
    - What distinguishes science from other disciplines, such as religion or art?
- The TA should scaffold students to understand the role of empirical evidence in science. Once students comprehend that science is based on empirical evidence because scientific knowledge is based on and/or derived from observations of the natural world, move to the next question.

- What is the role of the "scientific method" in formulating knowledge that has been discovered?
- The idea of the scientific method being an objective and fixed process by which the knowledge is discovered is a common misconception. In fact, the scientific method plays no role in separating science from other disciplines. The TA should point out here that there is more than one scientific method that scientists follow to do their work.
- The TA should confirm that students know when a hypothesis is usually made in the scientific method and relate it to forming a hypothesis in the finch activity.

- Students do Activity # 2
- "Once students have considered as many different hypotheses as possible, they must choose the most accurate one by the process of elimination. Again, using data and observations, the student should be able to disprove, and thus eliminate, several of these hypotheses. It is important for students to find data and observations which reject alternative hypotheses. Students are reminded that if they have several plausible hypotheses and no evidence to reject any of them, then any of them could be plausible. In an ideal world, the data would lead the student to reject all possible hypotheses except one, and this one hypothesis would be solidly supported by all available evidence."

- The TA now poses the following questions:
- Does scientific knowledge change, or is it absolute? For example, once a theory such as evolution or plate tectonics has been developed, is it subject to change? Explain why or why not? Give examples if possible.
- Yes. Theories and laws are tentative and subject to change with new observations and with the reinterpretations of existing observations. Scientists are never completely sure of