This material is based on work supported by the National Science Foundation under Grant No. DUE 9987332.

TxCETP Course Component:

# Understanding Scientific Inquiry
# "The fly, the raven and the scientist"

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## I. Introduction

Overview of Course Component:

The Scientific Inquiry Course Component is designed to facilitate an appreciation for, and an accurate assessment of, the nature of scientific approaches to solving problems. The activities included in the Course Component require students to: 1) acknowledge potentially inaccurate, prior conceptions regarding the nature of science, 2) apply their understanding of the scientific process to a new scenario and 3) actively develop a higher level of appreciation for the scientific accomplishments discussed throughout the course.

Objectives of Course Component:

The student is expected to develop an appreciation for the scientific process and during the activities associated with the Course Component, students will: clarify their understanding of the nature of science, plan and implement investigative procedures, develop scientific questions, and formulate testable hypotheses. They will also analyze, review and critique scientific explanations as to strengths and weaknesses.

Overall Time Frame for the Course Component:

Approximately two, fifty minute classes, plus 20-30 minutes in several subsequent lectures

Prior Knowledge: None

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## II. Activities

### Inquiry A: *The Scientist*

Objective: Students confront their prior conceptions about the nature of science and scientific inquiry.

Time Frame for Activity: 30 - 40 minutes

Materials:

1. Examples of scientific and non-scientific knowledge (See Appendix of Resources)
2. Class roll divided into heterogeneous groups of three using the following criteria:
    a. classification
    b. intended major

Procedure:

1. Get the students into the heterogeneous teams.

2. Individually, students list examples of what they each consider to be scientific truths. No class or group discussion at this point.

3. Hand out list of examples of scientific and non-scientific knowledge (1 list per group) and in their groups have students label those examples as scientific or non-scientific.

4. Discuss the basic tenets of science (repeatability, tests are done in the context of natural law, tentative nature of science, requires objectivity, questions asked must be testable, etc.) and use the items from the list described in Step #3 as examples of adherence or non-adherence to those tenets.

5. Informally, ask the students how accurate their group was in distinguishing between scientific and non-scientific knowledge.

6. Based on the tenets of science, ask each student to re-examine his/her list of scientific truths and with the help of the group, make any changes necessary (in a different color of ink, preferably). A discussion of scientific truth as opposed to truth based on faith, etc. may develop at this point and would be ideal!

Formative Assessment:

1. What new concepts have you learned regarding the nature of science?
2. What misconceptions regarding the nature of science did you possess before today's class?

Collect the list of scientific truths each student wrote and then modified (if modification occurred!).

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## Inquiry B: *The Fly*

Objective: Students design an approach to solving a particular problem using the scientific method as they understand it prior to class and then modify their approach following a discussion during class which will clarify the nature of the method and its proper use.

Time Frame for Activity: 50 minutes

Materials:

One copy of Chapter 3 from To Know a Fly (See Appendix of Resources) for each student

Procedure:

1. Students are placed into the heterogeneous teams they were in during the last class period.

2. Students have 10 seconds to write a definition of the Scientific Method. Upon completion, students put their definitions aside.

3. Class discussion on flies begins, including how flies behave when they land on food. The discussion should adhere to the tenets of science discussed in the previous class. Questions such as, "What are the flies doing? Do they seem to prefer some foods to others? How can they sense different tastes, or do they?", etc. may help guide the discussion.

4. Students are asked, "How are flies able to sense different tastes?". Students work in their groups and devise an investigation which addresses this question/problem that will be turned in at the end of class. The design of this experiment must ultimately include the following:
   - Personal observations of flies
   - Question upon which they are basing their hypothesis
   - Written hypothesis
   - Experiment to test the hypothesis (includes a control, replication, etc.)
   - Predicted outcome
   - Other experiments based on predicted outcomes

5. As the students work, the photocopy of Chapter 3 is given to each student.

6. When the group has finished writing their investigation, the students read the handout.

7. As the students read Chapter 3 (should take about 9 minutes at the most), the following question (one per group) is handed out FACE DOWN, "How did your experiment differ from that described by the author and what changes (if any) do you think you need to make in your design?"

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8. When each group is finished reading, they turn over the question and begin composing an answer to that question on the page containing their investigation outline.

9. When the students are done, a discussion begins which solicits recognition of the scientific method and some of the key points associated with it, such as:
    1. the nature of good scientific questions and hypotheses (good opportunity to tie in the basic tenets from previous period)
    2. qualitative vs. quantitative observations
    3. value in the universality of the method
    4. the importance of repeatability and its power to derive solid scientific explanations.

10. Students re-evaluate their 10-second definition.

Formative Assessment:

1. Ask the students to re-evaluate their 10-second definitions and working in their groups, decide how or if they would modify their respective definitions.

2. Collect the investigations and definitions of scientific method.

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## Inquiry C: *The Raven*

Objective: Students read initial scientific observations from actual case studies and develop their own investigative strategies for each case study. Appropriate case studies are used as introductions to various topics throughout the course and the procedure for this activity may be used at that time.

Time Frame for Activity: 20-30 minute introduction for related topics throughout the course

Materials: A copy of *Ravens in Winter* and summary with instructions. (See Appendix of Resources)

Procedure:

1. Students return to their heterogeneous teams OR may work individually.

2. Case study is distributed and read during class.

3. Students design an investigation to solve the problem presented in the case study.

4. Students compare their designs to those used in the case study.

Note: Using class time for reading this first case study and designing an investigation allows for discussion of the case study itself and clarification of the assignment. Future case studies could be distributed and assigned to be read outside of class and followed up with an investigation also written outside of class. The first case study selected should be one that would introduce a topic which normally follows discussion of the scientific method in the course.

Formative Assessment:

1. What was the most difficult part of writing your investigation for this case study?

2. How was your investigative design different from the case study's author?

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# III. Assessment & Evaluation

Pre-Test Questions for the Course Component *Understanding Scientific Inquiry*

**Inquiry A Evaluation**

1. Which of the following questions would be considered “scientific”?

   A) What is the effectiveness of this cancer-fighting drug?
   B) Which religion is best?
   C) Which painting is more attractive?
   D) Which model is more attractive?
   E) Which political party is best?

2. Which of the following are considered to be basic tenets of science?

   A) objectivity.
   B) measurability.
   C) explanations are tentative.
   D) a and b.
   E) a, b, and c.

3. Write a question which would be considered "scientific".

4. Write a question which would not be considered "scientific".

5. Explain your rationale for your answers to questions #3 and #4.

6. Name five basic tenets upon which science must adhere.

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## Inquiry B Evaluation

1. Your friend was recently cooking potatoes and wondered why cubed potatoes cook faster than whole potatoes. Your friend thinks that the water boils more quickly with the cubed potatoes. They devise an experiment. Four identical ceramic bowls are filled with equal amounts of water on four identical hotplates. A whole potato was placed in the first, halved potatoes in the second, a cubed potato in the third, and no potatoes in the final bowl. The container with the cubed potatoes boils first and your friend concludes that his hypothesis was correct. What is wrong with this scenario?

   **Choose all that apply.**
   A) Potato size was not standardized.
   B) There were not enough replicates of the experiment.
   C) There were too many uncontrolled variables.
   D) There was no control in the experiment.
   E) The question posed by your friend is not testable using scientific inquiry.

2. What are the common "sins" committed in the name of science? Why is this the case? What are the implications of these sins?

3. Describe your experiment. How does it compare to Dethier's experiment? Identify your variables and controls.

4. What is wrong with the flea and intoxication experiments described in the reading from Dethier?

5. What are some common fallacies in scientific inquiry? Describe some of the good practices used in scientific inquiry.

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## Inquiry C Evaluation

Based on some observation your instructor assigns, design an original experiment that would be scientific in nature and would incorporate the tenets of science. Support your introductory materials and conclusions using appropriate references. Use the following evaluation rubric as a guide.

Some examples that could be used by instructors:

1. Why are horned lizard populations declining in size?
2. What are the pollinators of Yucca plants?
3. Why do rabbit populations increase in size during droughts in some parts of the world?
4. Maples are extremely common in the northern and eastern portions of the United States but rarely occur naturally in Texas. Why does one large population occur in the Hill Country of Texas?
5. A manager of a catfish farm is greatly concerned about large numbers of fish dying just before harvest time. How can you find out what is causing the catfish deaths?

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# IV. Appendix of Resources

## Contents

## Quiz

1. Which of the following questions would be considered "scientific"?

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   B) Which religion is best?
   C) Which painting is more attractive?
   D) Which model is more attractive?
   E) Which political party is best?

2. Which of the following are considered to be basic tenets of science?

   A) objectivity.
   B) measurability.
   C) explanations are tentative.
   D) a and b.
   E) a, b, and c.

3. Your friend was recently cooking potatoes and wondered why cubed potatoes cook faster than whole potatoes. Your friend thinks that the water boils more quickly with the cubed potatoes. They devise an experiment. Four identical ceramic bowls are filled with equal amounts of water on four identical hotplates. A whole potato was placed in the first, halved potatoes in the second, a cubed potato in the third, and no potatoes in the final bowl. The container with the cubed potatoes boils first and your friend concludes that his hypothesis was correct. What is wrong with this scenario?

   **Choose all that apply.**
   A) Potato size was not standardized.
   B) There were not enough replicates of the experiment.
   C) There were too many uncontrolled variables.
   D) There was no control in the experiment.
   E) The question posed by tour friend is not testable using scientific inquiry.

**Suggested Examples of Scientific and Non-Scientific Knowledge**

(Comments in parentheses are from the author)

1. What goes up must come down. (point view - gravity on Earth vs. universal theory)
2. Chamomile tea relaxes you. (folk "science" vs. lab science; place to put the history of science/women and minorities in science)
3. There are/is Supreme being(s). (allowing for either God or the existence of aliens to be discussed)
4. Sound moves slower than light. (measurable)
5. Monarch butterflies migrate south in the winter. (Observable with repeated observations required to verify)
6. There is a hole in the ozone layer. (terminology used by media – what is meant by "hole" does the media create misconceptions by "dumbing-down" concepts - could teachers do this?)
7. Cigarette smoking increases the risk of cancer. (difference between direct cause/effect and tentative nature of science)
8. Drinking alcohol is bad for you. (tentative nature of science, impact of variables and lack of agreement among different researchers)
9. The earth is closer to the sun in the summer. (possibly reveal some misconceptions - discussion of the difference between "common sense" and results of scientific measurement also discussion of frame of reference and problems associated with issues involving large-scale differences)
10. When water boils, the bubbles are filled with air. (another "common sense"/scientific reality conflict - after they think about it, they will say, "Oh yeah!")

The first list is more likely to promote thoughtful discussion that may even be initiated by the students and differences among their answers. This second list is just terms that would be less likely to initiate thoughtful discussion about whether the terms are supported by scientific thought/research. Discussion could be facilitated with the use of “why” questions.

1. Gravity
2. Supreme being(s)
3. $E=mc^2$
4. Astrology (which is often confused with astronomy)
5. Natural Selection
6. Commutative Property of Addition (agreement upon definition of terms, replicability)
7. Herbal medicine
8. Validity of ExCET scores vs. use of ExCET scores
9. Law of conservation of energy (direct vs. indirect)
10. Genetic theory (replicability)

The following page is a print ready form of the lists above. Please feel free to modify as desired.

**Scientific or Non-Scientific?**

1. What goes up must come down.
2. Chamomile tea relaxes you.
3. There are/is Supreme being(s).
4. Sound moves slower than light.
5. Monarch butterflies migrate south in the winter.
6. There is a hole in the ozone layer.
7. Cigarette smoking increases the risk of cancer.
8. Drinking alcohol is bad for you.
9. The earth is closer to the sun in the summer.
10. When water boils, the bubbles are filled with air.
11. $E=mc^2$
12. Astrology
13. Commutative Property of Addition
14. Law of conservation of energy

**Chapter 3 from *To Know A Fly***

## Case Studies

Ecologically-Related Case Studies:

Weller, H.G. 1998. A Running Inquiry - Nature Asked the Questions During this Jog. *Journal of College Science Teaching*. 27(6): 389-392.

Heinrich, B, 1989. *Ravens in Winter*. Simon &Schuster.

Assortment of Case Study Topics:

Hagen, J.B., D. Allchin, and F. Singer. 1996. *Doing Biology*. Addison-Wesley

## Additional References


Bybee, R.W. 1998. Teaching Science as Inquiry. *Teaching in the Inquiry-Based Science Classroom*. American Association for the Advancement of Science.

Cooper, J., and P Robinson. 1998. Small Group Instruction in Science, Mathematics, Engineering, and Technology. *Journal of College Science Teaching* 27(6): 383-388.

Dethier, V.G. 1976. *The Hungry Fly: a Physiological Study of the Behavior Associated with Feeding*. Harvard University Press.

Klapper, M. H. 1995. Beyond the Scientific Method: should science be taught as a more creative process? *The Science Teacher* 62(6): 36-40.

Hagen, J.B., D. Allchin, and F. Singer. 1996. *Doing Biology*. Addison-Wesley.

Heinrich, B, 1989. *Ravens in Winter*. Simon &Schuster.

Herreid, C.F. 1997/1998. What Makes a Good Case: Some Basic Rules of Good Storytelling Help Teachers Generate Student Excitement in the Classroom. *Journal of College Science Teaching.* 27(3):163-165.

Herreid, C.F. 1998. Return to Mars: How Not to Teach a Case Study. *Journal of College Science Teaching.* 27(6):379-382.

Schmier, L. 1995. *Random Thoughts: the Humanity of Teaching*. Magna Publishers, Madison, Wisconsin.

Schmier, L. 1997. *Random Thoughts II: Teaching from the Heart.* Magna Publishers, Madison, Wisconsin.

<u>Website References:</u>

http://vflylab.calstatela.edu
http://vquake.calstate.edu
http://cal-flylab.sonoma.edu
email contact for these sites: bob@chaos.calstatela.edu
http://www.project2061.aaas.org (numerous publications on current reforms in science teaching)

**Student Activity Sheet**

**Inquiry A: The Scientist**

Objective:
Students confront their prior conceptions about the nature of science and scientific inquiry.

Procedure:

1. List examples of what you consider to be scientific truths.

2. After your discussion of # 1, examine examples of scientific and non-scientific knowledge (provided by the instructor) and in your group label those examples as scientific or non-scientific.

3. After your discussion of #2, how accurate was your group in distinguishing between scientific and non-scientific knowledge?

4. Based on the tenets of science developed in discussions, re-examine your list of scientific truths and with the help of the group, make any changes necessary (in a different color of ink, preferably).

## Formative Assessment of Inquiry A

1. What new concepts have you learned regarding the nature of science?

2. What misconceptions regarding the nature of science did you possess before today's class? Collect the list of scientific truths each student wrote and then modified (if modification occurred!).

## Student Activity Sheet

**Inquiry B: *The Fly***

Objective: Students design an approach to solving a particular problem using the scientific method as they understand it prior to class and then modify their approach following a discussion during class which will clarify the nature of the method and its proper use.

Procedure:

1. After guided discussion, devise an investigation that addresses this question/problem that will be turned in at the end of class. The design of this experiment must ultimately include the following:
   - Personal observations of flies
   - Question upon which they are basing their hypothesis
   - Written hypothesis
   - Experiment to test the hypothesis (includes a control, replication, etc.)
   - Predicted outcome
   - Other experiments based on predicted outcomes

## Formative Assessment of Inquiry B

1. Re-evaluate your 10-second definition, and working with your group, decide how or if you would modify their respective definitions.

## Student Activity Sheet

**Inquiry C: *The Raven***

Objective: Students read initial scientific observations from actual case studies and develop their own investigative strategies for each case study. Appropriate case studies are used as introductions to various topics throughout the course and the procedure for this activity may be used at that time.

Procedure:

1. Design an investigation to solve the problem presented in case study presented as a guided discussion by your instructor.

## Formative Assessment of Inquiry C

1. What was the most difficult part of writing your investigation for this case study?

2. How was your investigative design different from the case study's author?