Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
1982 Volume II: Autobiography

Scientific Autobiography

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This unit is proposed for use as enrichment material for upper level high school students of chemistry and physics. These students are of average or above average ability and the majority of them are college bound.

Because this unit is not a part of the regular curriculum, but is intended to broaden the students' view of science, it will not follow the usual four to six week format, but will be used throughout the year at appropriate stages of the courses. Most of the work will be completed as out of class reading and writing assignments, with actual in class time held to a minimum. The tight scheduling of the mandatory subject matter units makes this type of approach necessary.

Hard Science courses almost always concern themselves exclusively with the subject matter of the disciplines, stressing the definitions, formulas and problem solving techniques involved in each. The great men and women of science are usually mentioned only in passing, as the discoverer of this process or the developer of that theory. Little or no consideration is given to the characters or personalities of the men and women themselves, or to the human and ethical problems that they faced as they made their discoveries.

In any society an individual is influenced by the social, intellectual and moral forces that surround him. Students will be asked to form their own opinions of the great men and women of science by looking at them through their own words as they appear in autobiographies, essays, letters and other papers.

I propose to have my classes study some of these writings as group projects. However, the major focus of the unit will be to encourage the students to read selections written by a scientist in whom they are particularly interested and to attempt to analyze the researcher and his work in the context of his environment. Students will then be encouraged to share their own insights and opinions with their classmates in a variety of ways, such as written and oral reports, laboratory skits and role playing.

It is hoped that by incorporating this study of the more personal aspects of the scientist and his work into the rather rigid curriculum of a science course, that the process of scientific research can be humanized. Perhaps this approach can make science more interesting to the students, especially to those students who prefer the humanities and who only take science courses because they must.

Objectives

1. To provide the student with some understanding of the nature of scientific research.
2. To formulate a framework for the study of the writings of individual scientists.
3. To read and analyze works written by scientists representative of the following periods:
    A. The Ancient Scientists (previous to the year 1000)
    B. The Renaissance Scientists (1400 to 1600)
    C. The forefathers of Modern Science (1600 to 1800)
    D. Scientists of the Modern Age (1800 to present)
4. To outline classroom activities for the sharing of information and the developing of insights.
    A. Oral Reports
    B. Writing Articles
    C. Laboratory Skits
    D. Role Playing

1. The Nature of Scientific Discovery

Scientific research is defined by the Random House dictionary as a “method of research in which a problem is identified, data are gathered and a hypothesis is formulated and empirically tested”.

This definition is probably adequate for the majority of scientific workers, from the lab technician to the engineer, but it fails to include the more intangible qualities that must be present in an individual to make him a truly outstanding scientist. He sees questions begging to be answered everywhere he looks. He takes nothing for granted. Such simple occurrences as an apple falling on his head creates avenues to explore. The successful scientist must be able to see familiar things and events in a new and different context. Things that most of us would not notice lead him to fresh discoveries. Each answer found presents new questions. He extrapolates from the barest hint of information far beyond the range of ordinary people. Penicillin was discovered because a scientist wondered how the presence of a moldy grapefruit in the lab was connected to a change in growth patterns of bacteria in a culture.

Does this intensified awareness of his environment, this attitude of constant questioning, spill over into the personal life of the scientist? Perhaps the words of the scientists themselves will answer this question as the unit progresses.

There are two opposing theories about the great advances in science. One, which I call the “eureka” theory, holds that a truly outstanding individual is occasionally born whose brilliant insights illuminate his generation,

and whose contribution alone is the cause of quantum jumps in knowledge. This view is supported by naming many of the great scientists, from Copernicus through Einstein, who produced ideas of such originality and importance that they were light years ahead of their peers. These men seemed, unaided, to have changed the course of history.

The opposition theory is sometimes called the “zeitgeist” theory, which in German means the “spirit of the times”. It insists that revolutionary ideas are a product of their generation. This theory proclaims that at certain intervals in history circumstances are ripe for new discoveries and that outstanding individuals merely play their preordained roles in developing them. Those who support this theory claim that through the ages many equally able persons have existed, but that only those fortunate enough to have been born at the propitious moment in time make the momentous discoveries that occur.

This latter group bolster their claims by citing the occasional duplication of work by contemporary scientists with no knowledge of each others work. The development of the theory of evolution by both Charles Darwin and Alfred Wallace at the same point in time is just one example of this phenomenon. The simultaneous development of the advanced system of calculation known as calculus by two men working independently of each other is another example.

Through the careful study of excerpts from articles, books and letters written by successful scientists, we will attempt to answer the following questions.

1. How was the writer’s work affected by the climate of his generation? Does he appear to have shaped the times in which he lived, or does he appear to have been the medium for a natural progression of knowledge?
2. What moral and ethical problems were involved in the work of the individual and how were these dilemmas dealt with? Did he ignore the implications of his work and concentrate only on the quest for knowledge?
3. What seemed to be the motivating factor in the life of the researcher? Was it the search for knowledge for its own sake, the quest for practical solutions to problems that existed, or was it a desire for such things as economic success and recognition?
4. What traits of intellect and personality, if any, do these people seem to have in common? Does there appear to be something that differentiates them from the general population, that sets them apart as a group?

I have put together a small collection of letters, articles, essays, and excerpts from books written by scientists from various periods in history. This will be available from the Institute in a classroom set and I would recommend it as a convenient source of reading for students during this unit.

Some time should be taken at the onset of the year to discuss the meaning of the terms science and scientific method. The first three pages of the anthology I put together contains brief descriptions of the aims of science in the view of several eminent scientists.

A series of nine films called *The Search for Solutions* is available free of charge from the Phillips Petroleum Company. These films discuss all aspects of the process of scientific discovery and rely heavily on interviews with prominent scientists in which they talk about their work. More than one hundred and twenty six scientists participated in the project and I cannot overemphasize the excellence of the films. They are entertaining as well as informative and will greatly enhance the students understanding of the scientific process.

The Ancient Scientists

In reading the words of our earliest scientists, it is important to remember that they lived in a society which attributed all things that could not be readily understood to the activities of the gods or to magic. Men lived in terror of evil spirits and such unthinkable entities as vengeful deities were very real to them. What was truly remarkable about such men as Galen and Hippocrates was their painstaking and detailed observations of things they encountered in an attempt to make some sense of the forces of nature.

These men carefully observed what they saw and accurately recorded their observations. As they did so, patterns of events began to emerge which formed a basis for somewhat reliable predictions. As cause and effect relationships began to emerge, superstitions faded. Events which can be foretold tend to lack the ability to terrify. In gaining some understanding of the natural world, man began to gain a control of his own destiny which had not been previously possible.

There is, of course, not a great deal of literature available from this period. Students will be asked to read excerpts from Hippocrates and Aristotle which can be found in the anthology.

The following questions should be used for discussion of the works of Hippocrates and Aristotle.

1. Can you get any feeling of what life was like during their lifetime from the things you read?
2. What aspects of the scientific method, as we know it, can be found in their work?
3. What moral problems can you identify as you read?
4. How important do the moral problems involved in their work appear to them?
5. From what you know of that period in history, would you say these men would most exemplify the eureka or zeitgeist theories?

Scientists of the Middle Ages

The period of time from the birth of Christ to the fourteenth century is known as the Dark Ages. Scientific progress faded and superstitions reigned supreme. Those who dared to dabble in science with any success invited the wrath of the church and were usually accused as heretics or witches. The only record of a scientist of this era available was written by Roger Bacon in the eleventh century. His description of science can be found at the beginning of the accompanying collection.

The fifteenth century saw a reawakening of the spirit of discovery, probably sparked by the reappearance of the works of the early scholars. The following list will be suggested to the students and articles written by

each are included in the accompanying material.

Andreas Vesalius—founder of modern human anatomy
Nicholas Copernicus—placed the earth in its proper place in the heavens
Galileo Galilei—inventor of the telescope
William Harvey—physiologist

After reading Vesalius, the following questions are suggested for discussion:

1. What seemed to be the primary purpose of the essay?
2. What information about the climate of his era can be inferred from his words?
3. Does his work seem to be revolutionary or a natural outgrowth of the period in which he worked?
4. How easy to understand is the reasoning of each of the gentlemen above?

Students should be reminded that most of the things these men studied and wrote about were new concepts at that time. It may make the reading more interesting if the class first tries to put themselves in the place of a citizen of that period who held the accepted ideas when reading these articles. For instance, we could pretend as a class to firmly believe that the earth is the center of the universe when reading Copernicus and Galileo. In that context we can judge how convincing they are.

The Forefathers of Modern Science

During the seventeenth and eighteenth centuries the basis for modern methods of scientific research was built. The emphasis on experimentation was elaborated and the necessity for accepting only those facts that could be corroborated was stressed. From this period the included writers will be -

Anton Van Leeuwenhoek—first to use the microscope
Daniel Fahrenheit—inventor of the first mercury thermometer

When reading Van Leeuwenhoek, students should be asked to describe his attitude towards his work, as well as considering the questions that were discussed after studying Vesalius. Does this attitude seem to be typical of the scientist, or an isolated case?

In his article, *A Personal Story of Invention* , Mr. Fahrenheit succinctly explains invention. It would be interesting here to have students try to identify the various components of the scientific method used by Mr. Fahrenheit.

Scientists of the Modern Age

Modern man invests the scientist with almost mystical powers. We tend to look to science for the answers to all problems. We appear to have gone full circle from a rejection of science to a blind faith in its powers. During the past century as the modern sciences grew to maturity, the researchers themselves seldom questioned the value of their work. However, in this century many articles have been written by scientists trying to put their work and the work of their contemporaries into proper perspective. There is so much material available to the student that the problem will be in selecting that which is most appropriate.

Students will be asked to select readings from the following groups, many of whom have been included in the accompanying copies.

* Included in anthology

Chemistry: Joseph Priestley—discoverer of oxygen
Antoine Lavoisier—Father of Modern Chemistry *
John Dalton—The Atomic Theory *
Ernest Rutherford—Atomic Structure

Physics: Michael Faraday
Joseph Henry
James Joule
Hertz
Lord Kelvin—Thermodynamics
William Roentgen—Discovery of X-ray
Eve Curie—Discovery of Radium *
Albert Einstein—Theory of Relativity *
He also wrote many books and articles on social moral issues as well as science.
J. Robert Oppenheimer—Physics and the Contemporary World*

Energy and Electricity

Medicine: Edward Jenner—Vaccination
Crawford Long—Anesthesia
Joseph Lister—Antiseptics
Louis Pasteur—Germ Theory of Disease

Other: Ben Franklin—First Great Name in American Science *
Thomas Henry Huxley—Science and Culture *
Rachael Carson—The Environment *

There are also several books available that students might enjoy reading in their entirety. The autobiographies of Ben Franklin, Dr. Charles Mayo and Albert Schweitzer are examples. *The Double Helix,* written by Dr. James Watson about the model of the DNA molecule, is an excellent blend of scientific and personal problems involved in scientific discovery.

Because Oppenheimer was such a great scientist, and because he so obviously was deeply affected by the moral consequences of his work, he should be read by all students in the class. They should be prepared to discuss as a group the following questions about his life:

1. What facts led to his great concern about the repercussions of the work of the research scientist?
2. How well do you feel that he coped with these concerns?
3. How does he view the proper role of the scientist in the modern world?

Activities

1. After reading selections of particular interest to himself, each student will be asked to share his knowledge with the rest of the class. He should attempt to answer the questions we have been considering during the study of each period and to support his conclusions.
   Would the work of this scientist support the eureka or the zeitgeist theory of discovery?
   What appeared to have most motivated the researcher in his work?
   What was the exact nature of the problems, personal or scientific, that troubled the scientist?
2. Students will be divided into small groups of four or five and asked to produce a short skit in the lab of the following situations, using appropriate props.
   A. One person, convinced that Copernicus is correct in his theory that earth is not the center of the universe, attempts to convince three non-believers.
   B. A physician in the 19th century, converted to the germ theory of disease, tries to convert three fellow workers that disease can be spread by unwashed hands and instruments.
   C. Four workers on the atomic bomb in the second world war discuss their work.
   Worker l—desires fame and recognition for their magnificent work.
   Worker 2—is excited by the thrill of the pure scientific discoveries and this overcomes all other considerations.
   Worker 3—is in mortal fear of the terrible devastation that may result from their work.
   Worker 4—is vehement in his desire to use the bomb on the hated enemy and end the war quickly.
   Each worker is attempting to bring the others to share his point of view.
3. Each student will be expected, during the spring term, to write a short essay in which the following information is included.
   A. the student's own description of the process of scientific discovery known as the "scientific method".
   B. a general description of the intellectual and personality traits that seem to be possessed

by most scientists, as shown by the things we have read.

C. An opinion, supported by reading we have done during the year, as to the validity of the zeitgeist or the eureka theories of scientific discovery.

D. Has scientific progress gotten out of control and are such things as nuclear power, genetic engineering and organ transplants leading to the self-destruction of man or to an enlightened and much improved future?

Bibliography (student and teacher bibliography are the same)

Einstein, Albert, *The Impact of Modern Scientific Ideas on Society,* Hingham, MA: D. Reiden Publishing Company.

Franklin, Benjamin, *The Autobiography and Other Writings* , New York: Signet Classics, 1961. A readable, interesting autobiography of the first outstanding American man of science (among other things!)

Gardiner, Martin, ed., *Great Essays in Science,* New York: Washington Square Press, 1970. A collection of thirty essays by leading scientists on the characteristics of scientific enquiry and the philosophical questions involved.

Judson, Horace Freeland, *The Search for Solutions* , New York: Holt, Rinehart and Winston, 1980. A marvelous book attempting to describe scientific investigation, and including many conversations with contemporary scientists on the nature of their work.

Moulton, Forest and Schiefferes, Justus, eds, *The Autobiography of Science,* New York: Doubleday and Co. A

collection of letters, essays and papers of the worlds greatest scientists through the ages.

Oppenheimer, J. Robert, *Robert Oppenheimer—Letters and Recollections,* A collection of the chronicles and problems faced by this brilliant man.

Schweitzer, Albert, *Out of My Life and Thought* , New York: New American Library of World Literature, Inc., 1963. An inspiring life story of a man of science who put humanitarian values above all others.

Watson, James D., *The Double Helix* , New York: The New American Library, Inc., 1969. A very well written and interesting description of the scientific and the personal problems involved the great breakthrough in genetics—the structure of DNA.