**Nuclear Energy: Friend or Foe?**

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## Introduction

It has been my experience that atomic or nuclear physics, especially the topic of nuclear energy, has been ignored by secondary physics teachers in their classrooms. Why? Physics teachers that I have spoken to say there are too many other critical concepts that need to be covered and therefore, not enough time to teach nuclear physics. Other teachers feel that this topic is best taught in Chemistry. A glance at the textbooks used in Physics and Chemistry courses confirms that nuclear processes are acknowledged, but placed at the end of already content laden texts. Does this send the message to educators that the material is not important or may be covered only if time permits?

The goal of this unit is to show teachers a way to incorporate nuclear physics into their existing curriculum. Although the unit design is intended for secondary Physics, it can be readily adapted for an Environmental Science, Chemistry, or General Science course. This unit can be taught independently or with the concepts of work and energy. In any case, the unit must be brought from the back of our textbooks and put to our students as a topic that deals with real- life science issues.

The overall objective for students is to develop and defend their point of view concerning the controversy surrounding nuclear energy and how to best manage it's waste. Students will be given a history of atomic physics, key vocabulary, and information about nuclear processes. Nuclear energy will be a focal point of the unit about which all other content revolves. Research on the role of nuclear energy will conclude the unit. Students will conduct a classroom discussion in hopes of finding solutions to problems that arose from their research.

The unit is deeply rooted within the Core Curriculum Frameworks of the Pittsburgh Public Schools. The unit crosses the academic borders of Science and Technology into Environment and Ecology as well as Communications standards. The class time needed can be as short as a week, depending upon the activities planned.

## I. Historical Development of Atomic Theory

The unit begins with the historical development of atomic theory in modern times (less than 200 years ago). The objective for students is to evaluate how scientists have contributed to technological advancements. In this case, the technologies deal with atomic structure that has an essential role in the development of nuclear weapons and energy.

The standard met in this situation would include the first standard cited in the Pittsburgh Public Schools Core Curriculum Frameworks in Science and Technology. The standard states that all students explain how scientific principles of chemical, physical, and biological phenomena have developed and relate them to real-world situations. The principle of atomic structure, especially the nucleus, crosses the borders of physics and chemistry. Both disciplines have a stake in this knowledge and also share the benefits thereof.

The real-world situations in which these inventors have influenced are far and wide. Specifically, the whole notion of the atomic nucleus gave rise to the fields of nuclear physics and chemistry. The offshoot of this knowledge has led to the technology of nuclear weapons and processes used in nuclear energy production. Students need to make the connection of what they already know or think about nuclear issues and reinforce their understanding of current scientific knowledge regarding such issues.

### Session 1
### Teacher Recitation on Key Scientists

Key scientific thought and discovery of nuclear or atomic physics will be addressed in a thirty-minute recitation. Students will be given names and a brief description of the key scientists involved in atomic or nuclear areas. The focus will include such scientists as William Crookes, Antoine Becquerel, J.J. Thompson, Marie Curie, Ernest Rutherford, Wilhelm Rontgen, Albert Einstein, and Enrico Fermi.

### Session 2 & 3
### Activity 1 - Research a Scientist

Students will then be asked to do research on a scientist given a list of choices. (See enclosed list - Scientists of Atomic Theory) Students will be given a scheduled lab period (60-70 min) for research time in the school library. They will also write from a prompt, which will include the following:

1. Name of scientist.
2. Date of birth and death.
3. Nationality.
4. Other personal information.
5. Educational background and colleagues.

6. Scientific contribution and awards.
7. Effect of contribution today.
8. What was most interesting?
9. List of research sources used.

The paper can be worked on in class or at home depending on the time frame being used. A rough draft will be due three days after research time has been given. All students will be required to type the formal copy of the paper. The length of the paper, all elements included, will be no more than two pages, single or double-spaced. Font size will be limited to 12 point and at least two sources of research must be utilized. This activity will be used as practice for their final research paper.

Assessment of the activity will be based on whether or not guidelines were followed while writing and researching their subject. Emphasis will be placed on the students' understanding of the effect of their scientist's contribution. Students need to make a link from the "boring" world of history to how that history affects their everyday life.

**Session 4**
**Development of Atomic Models**

Evidence for the existence of atoms may be credited to a botanist named Robert Brown when demonstrating spores that moved constantly. Brownian motion as it has been called, is today known to be the result of unseen atoms surrounding the object in motion. (1) More recently, atomic beams ( high energy electrons) have been used to take pictures of atoms when used with scanning electron microscopes and scanning tunneling microscopes.

Models of the atom were seen as early as John Dalton (1766-1844). The atom was viewed as a solid mass that was not able to be broken apart. However, Dalton's theory did also include the idea of invisible atoms. It was the discovery of subatomic particles that would shatter this view of the atom.

The nucleus of an atom was discovered in 1909 by a New Zealander physicist named Ernest Rutherford. Rutherford's Gold-Foil experiment used a beam of alpha particles from a radioactive source and directed it through thin gold foil. By studying the angles of deflected particles on a zinc-sulfide screen, Rutherford was able to show that the deflected particles must have repelled off the massive center of the charged gold atoms, while the particles that did not deflect must have traveled through empty space.

To reinforce the idea of atoms having a massive center surrounded mostly by space, a brief demonstration will be done. A quarter will be securely attached to the center of a small cardboard circle. (About the diameter of a coffee can lid.) The circle is then presented to students with the quarter on the back side. Either myself, or a student volunteer will randomly place a sharp, pointed object through the cardboard.

If the object is able to pass through the cardboard, then this simulates particles that penetrate the space around the atom. When the quarter stops the object from passing, this represents particles hitting a massive substance, which is likened to the nucleus of an atom.

It was around the turn of the century when J.J. Thompson (Joseph John) revised the model of the atom. Thompson described what is known as the “plum pudding model” of the atom because it was a ball of positive charge containing a number of electrons. Even though this model accounted for some electron charge, it did not address the nuclear make-up or idea of why electrons do not fall into the nucleus.

In the early 1900's, Niels Bohr, a student of Rutherford, proposed that electrons orbit or circle around the nucleus. This model was similar to the planetary motion around the sun. Because the electrons have fixed energy, they do not lose it and fall into the nucleus. Electrons move “levels” as they gain or lose energy.

It is the most modern view of the atom that maintains that the atom has no definite shape and that electrons do not have precise orbits. This model is called the quantum mechanical model and is based on quanta of energy being responsible for electrons changing energy levels of an atom.

**Session 5**
**Activity 2 - Drawing and Making 3D models of the Atom**

Students will be given instructions to make a visual time line of the different historical models of the atoms. Groups of two or three students will cooperatively complete the activity which includes drawing and labeling each kind of model, Identifying the scientist involved in it’s model, and giving a brief description of each kind of atom. Resources for the activity will be class notes and Chemistry/Physics textbooks. Materials needed will include: Posterboard, colored pencils or markers, and reference textbooks.

**Activity 3 - Atomic Structure Video**

A video on atomic structure, if available, can also be used to reinforce atomic structure to the students. A twenty-minute video may be used with a corresponding worksheet. This can be an alternative to, or reinforce concepts learned in Activity 2.

## II. Content Background: Nuclear Processes

The objective for the second phase of the unit is to import to students' knowledge of the atomic nucleus, radioactivity and nuclear applications. Nuclear physics has been involved in such areas as the arms race, energy production, and medicine. Students will focus on nuclear energy systems, but will be exposed to the nuclear weapons program as well as medical uses of radioactivity.

A brief description of alpha, beta, and gamma particles will be given at this point in the unit. Emphasis will be placed on the penetrating power of each type of particle. Students will draw and label a diagram of three metals, each below the other. Copper will be on top, aluminum in the middle, and lead on the bottom. Students will hypothesize as to which type of particle will reach the lowest metal. The class will then discuss what actually would happen given this scenario.

Students will use a worksheet to calculate the amount of radiation they are exposed to from natural and man-made sources. The determination stems from where one lives, what one eats, and how much exposure is received in everyday activities. Minimum and maximum dose amounts will be discussed as well as the units rem and mrem. Overall, the exercise brings to light the fact that radiation is real but invisible and excessive quantities should be avoided if possible. This information will also serve as a guidepost for vocabulary as the students engage in research on radioactive nuclear waste.

Standards met will include the second content standard of the Pittsburgh Public Schools Science and Technology Frameworks. This states that all students demonstrate knowledge of basic concepts and principles of physical, chemical, biological and earth sciences. Atomic structure, radioactivity, and nucleus systems would be considered to be both physical science and chemistry.

### Sessions 6, 7 and 8
### The Atomic Nucleus, Radioactive Decay and Half-Life

Students will take notes from teacher recitation about the make-up of the nucleus. Such information as nucleus, strong force, mass and change of the nucleus and isotopes will be explored. Students should be able to:

1. Differentiate between the two kinds of nucleons in the nucleus.
2. Compare the number of different nucleons found in the nuclei of different elements.
3. Describe the effect of the strong force.
4. Explain what a nuclide is and how an isotope differs from other atoms.
5. Recognize the operation of particle detectors and accelerators.
6. Describe the quark and lepton model of matter.

7. Explain the role of force carriers.
8. Define antiparticles.
9. Summarize how smoke detectors work.

The next topic to explore is radioactive decay. Students bring with them a limited and sometimes distorted view of radioactivity. Students will be asked to share what they know of this topic and to either reinforce or replace existing knowledge with scientific facts. This process will also be utilized when students are confronted with the topic of nuclear energy. Finding facts and destroying myths will become an important skill for students to take away from the classroom.

The main areas to be discussed are the types of radioactive decay and how to visualize the process through reactions and equations. By the end of this discussion students will be able to:

1. Distinguish among the three types of rays given off by radioactive nuclei.
2. Solve basic nuclear equations.

Half-life is the time required for half of the atoms in any given quantity of radioactive isotope to decay. Isotopes have their own particular half-life. Students will be given examples of different isotopes for a variety of elements, as well as their half-life and type of radiation produced. Model problems will also be done in how to calculate the amount of matter left. More advanced classes can also calculate the decay rate remaining after a number of half-lives. Students completing this section will be able to:

1. Define Half-life.
2. Predict, given the half-life of radioactive isotope and the original amount of the isotope, how much will remain at the end of some multiple of that half-life.
3. Explain the uses of carbon dating.

**Activity 4 - Guided Reading Activity**

Each student will be asked to read the appropriate material in their textbooks. A study guide will be issued to guide the reading process. This is to be a homework assignment meant to raise questions and reinforce classroom discussion. The study guide includes key vocabulary matching, multiple-choice questions, tables, and a short answer section. Some material to be read will not be covered in class but is reviewed on the reading activity. Students will be aware that all related material is not covered in the classroom but is still their responsibility to learn.

**Activity 5 - Physics Lab; Graphical Model of Half-life**

The purpose of the lab activity is to develop an understanding of half-life and radioactive decay. Student teams will be asked to use pennies and a shoebox to gather data on exponential decrease that is representative of decay. Each team will be asked to shake up a box with one hundred to two hundred pennies. Then, they will remove all pennies with the head side up, continuing the process until all the pennies are gone.

Graphing the number of pennies remaining after each shake verses the number of shakes will yield a curve that is indicative of half-life. Students will be required to apply prior knowledge on how to make a good graph. Lastly, analysis questions concerning the graph will be answered.

To demonstrate a longer half-life, students could roll dice and remove only the "one" rolls. They would continue to do so until all of the dice were removed. This experiment would be equated to those radioactive isotopes that have many years for half-lives.

**Session 9 and 10**
**Nuclear Fission, Nuclear Fusion, and Nuclear Reactors**

The culmination of content infusion will be learning the differences between fission and fusion reactions. Each type of reaction holds additional information such as a chain reaction during fission and types of fusion reactions. Students will also be able to describe the operation of one or more nuclear reactors. The learning will again take place in a traditional classroom setting via large group recitation. Students will be required to read the textbook and answer questions for homework.

A large group discussion on nuclear accidents will allow the students to gain some knowledge of potential negative effects of having nuclear reactors. The two most publicized incidents, Three-Mile Island and Chernobyl, will be explored.

As stated throughout this part of the unit, assessment will be in traditional textbook exams, labs, and homework. This will be a new teaching area for many and each time it is taught, more models and information can be added to modify the unit.

**Activity 6 - Chain Reaction Lab**

The lab will use dominos and a stop-watch to simulate a simple chain reaction. Dominos are set up in two different arrangements, linear and in a group. They are timed as they fall and each time and sequence is compared. The dominos are to represent the neutrons released by uranium atoms when they fission. The chain reaction of the dominos are witnessed and compared to the similarity of an atomic fission process. One domino will knock down two others, each of those will in turn knock down two more, etc.

A homework assignment or class demonstration of a probability situation can be added to this part of the teaching. The goal is to find the hypothetical long-range probability of a nuclear reactor accident. Six dice would be used with the roller representing a "reactor" and the dice a "year". Each time six sixes are rolled, a minor accident is probable. If eight sixes are rolled together, then the total number of throws would represent the years it takes for a probable major accident. Most students will not attain the probable situations in a class period. In any case, students will better comprehend the nature of predicting the likelihood probable future situations, such as a nuclear meltdown.

## III. Ethical Implications

The objectives for this section arise from the need for students to be able to think critically concerning an everyday science issue that will impact their lives. Therefore, the majority of time spent will be doing research and taking a position on an ethical issue. Since the nature of the assignment will involve higher level thinking, there will need to be a method of training students in ways to approach a multifaceted issue. A step by step system will be employed for this purpose.

There are two Pittsburgh Public Schools Curriculum Framework standards that are equally applicable to this learning. The first is the Ecology and Environment standard which states that all students think critically and generate potential solutions to environmental issues. (2) Higher level thinking will be needed when students evaluate their research data in order to determine their position on the nuclear energy issue. It will be recommended that students aim to outline a cost-risk-benefit analysis of nuclear energy production.

The second applicable standard for this type of work would be in the Pittsburgh Public Schools Core Curriculum Frameworks for Communication. (3) The standard calls for students to use effective research skills and information management skills. These include locating primary and secondary sources of information with traditional and emerging library technologies. Students will have access to current on-line search programs as well as traditional means for finding sources.

### Session 11
### Energy Production and Consumption

This class time will be a one period overview of the current energy situation nationally and globally. Charts and graphs will be an integral part of showing students the role of the United States in terms of energy and specifically the part that nuclear energy production plays. Fossil fuels will be briefly discussed as well as alternative forms of energy. Students will leave the period with a general foundation of where energy resources are located and the rate at which they are being used.

**Sessions 12 and 13**
**Research at the School Library**

Students will spend at least two scheduled periods of time at the high school library. The librarian demonstrates to the students the appropriate methods for researching their topic, as well as, introducing any new technology that is available to them. Students will also focus on the goal which is to research the topic of nuclear energy.

A writing prompt will also be used again as a list of questions that need to be addressed in their paper. The paper itself should be limited to two pages, single spaced in twelve point font. This does not include the bibliography or cited resources that must accompany the paper. Students will have all the necessary tools to create a short research paper on a specific subject.

**Sessions 14 and 15**
**Activity 7 - Ethical Issue Skill Training via Dilemma Worksheet**

The final step of instruction will occur when the students are guided through a case study of an ethical issue in science. A case study will be used to demonstrate to students the key players and characteristics of a potentially difficult decision making process. Such topics as gene therapy, gun control, animal research, and new reproductive technologies can be placed in a problematic form. This information should be read and analyzed by the students.

Students will then be asked to find the facts, identify the ethical problem, determine the stakeholders, examine their personal values, and give opinions, options and possible solutions to the problem at hand. They are also asked to predict the consequences that their solution will have on others. This work can be done in class or at home.

The worksheet (see enclosed activity) would then serve as a foundation for small group (2-5 students) discussion and eventually lead to a whole class discussion. The class would brainstorm and come up with ideas and options on how to address or solve the problem. Consensus may not occur and does not need to be the final result of the activity.

After the classroom discussion, students will complete a few follow-up questions. The questions ask if they have changed their answers after the discussion and what they have learned from the experience. This reflection could be an integral part of assessment or a portfolio component.

**Session 16**
**Activity 8 - Summary Paper: Taking a position**

The synthesis of preceding activities and learning should be in the final topic paper turned in by the student. At this point, there needs to be evidence of sound scientific research done with the emphasis on defending a position based on reflection of the ethics surrounding the issue. The students should find it a challenge to do the following:

1. Research a topic for general information and without a bias of viewpoint.
2. Write a concise research paper explaining the pros, cons, and options for solutions.
3. Defend their position with scientific reasoning based on facts.

## IV. Assessment

**Research Leading to Persuasive Essay**

The research aspect of this unit will be a major indicator of the value of this curriculum. Students will be asked to research the topic of nuclear energy with the end product being a written defense of a position. Students will be given a rubric prior to writing their paper and additional discussion will take place on what constitutes a quality paper. Emphasis will be placed on scientific information.

The rubric will highlight the following parts expected in this paper:

1. Thesis statement

2. Body of the paper
   a. Organized content
   b. Supports main points
   c. States pros and cons of issue

3. Conclusion
   a. How well is their position defended
   b. Solutions to the problem

4. Writing Conventions
   a. Grammar and spelling
   b. Cited works
   c. Typed or written neatly

5. Rough Draft submitted for revising

6. Note cards used in writing process

Each area of the rubric will have a number rating that will correspond to both the quality of their paper and the points received for their grade. Most areas will have a total point range of one to five. One will represent a lack of necessary development where as five will represent an excellent application in that area. In this scenario, both assessment and evaluation are combined in one process.

Writing a persuasive essay that examines both sides of a controversial environmental issue is one assessment strategy recommended within the Pittsburgh Public Schools Core Curriculum Environment and Ecology Frameworks. (4) Another strategy for assessment that is built into the research is the idea of students making a final decision on an environmental issue. (5)

The actual writing of a research paper is an example of assessment for the Pittsburgh Public Schools Core Curriculum Communication Frameworks content standard which emphasizes effective research in locating sources of information with varied library technologies. (6)

**Sessions 16, 17 and 18**
**Activity 9 - Oral Presentation**

Another Pittsburgh Public Schools Core Curriculum Communication Framework standard to be met deals with the exchange of information orally. (7) Students will be asked to present their position within a smaller group and possibly to the whole class. Students will need to present an organized summary of their position and give a brief defense of their research, thereby making the connection from the textbook to their own knowledge of the issue.

A short rubric could also be used to assess this part of student learning. Effective group communication can be summed up as having been able to get the point across to others. Areas such as voice clarity, sequence of thought, eye contact, and checking for understanding are integral parts of effective communication.

**Activity 10 - Group Discussion**

The culminating activity for the unit will be a whole class discussion as to whether or not nuclear energy is a friend or foe. Students will be gently guided to look at the role of nuclear energy, the pros and cons of producing such energy, alternative energy sources and hazardous waste management. The class will have had the opportunity to first hear where their piers stand on the issue. They will brainstorm the pros and cons of nuclear energy and be asked as a group if any of their sources of energy are reasonable as a group. Students will need to come up with one or more solutions to the controversy of nuclear energy.

The teacher will type the final solutions from each class and again have students vote on what they feel would be the overall most reasonable action. Lastly, each student will be given an evaluation sheet for the unit. They will be asked what they have learned, if they changed their position at all, what activity they enjoyed most, and what changes they would suggest.

## VI. Classroom Activities

### Activity 1 (part 1) - Scientists of Atomic Theory

Directions: Chooses a scientist to research. Be sure to cite all sources used to gather information.

William Crookes
Wilhelm Von Hofmann
Michael Faraday
James Maxwell
Heinrich Geissler
Joseph J. Thompson
Antoine-Henri Becquerel
Wilhelm Conrad Rontgen
Marie Curie
Pieter Zeeman
Oliver Lodge
Albert Einstein
Lord Kelvin
Francis Aston
Ernest Rutherford
Frederick Soddy
Guglielmo Macconi
Niels Bohr
William Ramsey
Hans Gieger
Otto Hahn
Lise Meitner
Paul Blackett
C.T.R. Wilson
John D. Cockcroft
James Chadwick
Max Planck
Pyotr Kapitsa
Enrio Fermi
J. Robert Oppenheimer
Edward Teller
Glenn T. Seaborg

### Activity 1 (part 2) - Writing Prompt for Student Research

Directions: The following information is required to appear in your biography of a scientist. Recall that your paper should be no longer than one side of a page, single spaced, with twelve point font.

1. Name of scientist.
2. Date of birth and death.
3. Nationality.
4. Contribution to science and how it impacts us today.
5. Other miscellaneous information.
    a. Where did he/she study?
    b. With whom did he/she work?

c. What awards were received?

6. Sources used for research

**Activity 7 - Ethical Dilemmas Worksheet**

Directions: Complete Part 1 of this packet after you read the ethical dilemma. Write down as much as you can: the more you can include, the better prepared you will be when you discuss this issue with your classmates!

Part 1 Answer each question as completely as possible:

1. What are the facts?
2. Identify and define the ethical problem?
3. Who are the stakemakers in the decision?
4. What values are at stake in the decision?
5. What options do you see are available to resolve this dilemma?
6. Which options are most compelling? Why?
7. How would you resolve the dilemma?
8. What values did you rely on to make your decision?
9. What consequences (if any) do you see your decision has on the others Involved?
10. Could you personally live with this decision? If not, re-examine your answers to questions 5 through 9 and examine other options to your dilemma!

Part 2: Now that you have had a chance to discuss your responses to Part 1 with your classmates, consider the following questions.

1. Have your answers to #7 and #8 changed? Why or why not? Is there Anything you would like to change or add? If so, list those changes.
2. List one value that you feel was reinforced by this ethical dilemma.

3. List one value that you feel you gained from this ethical discussion.

**End Notes**


1. Wibraham, Staley, and Matta, <u>Chemistry,</u> Addison-Wesley, 1997. (pp.323-326)

2. Pittsburgh Public Schools Curriculum Frameworks, “Environment and Ecology”, June 1996, p.26.

3. Pittsburgh Public Schools Curriculum Frameworks, “Communications”, December 1996, pp.7-8.

4. Pittsburgh Public Schools Curriculum Frameworks, “Environment and Ecology”, June 1996, p.26.

5. ibid.

6. Pittsburgh Public Schools Curriculum Frameworks, “Communications”, December 1996, p.8.
7. Ditto.

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**Technology Resources**

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