00D103I

Project Number: JMWNP08 46

A Contemporary Microcosm of the Nuclear Debate

An Interactive Qualifying Project Report

Submitted to the Faculty

of the

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Patrick J. Kaplo

May 1, 2000

Approved:

Professor John M. Wilkes

Abstract

Understanding the correlation between knowledge and opinion is the focus of a nuclear technology curriculum unit field test carried out in the Lancaster Middle School. A 64-student eighth grade study group was surveyed both before and after an intensive, five-week course in nuclear technology to determine if changes in opinion can be linked to the increase of topical knowledge. The Myers-Briggs Type Indicator (MBTI) was used to see if the unit was equally received by students with a broad spectrum of learning styles. Post-unit "retention" testing was employed to determine the project's effectiveness when compared to science class performance evaluations (grades) earned prior to the start of the nuclear unit.

Acknowledgments

Sincere gratitude is given to the following people who have contributed to the success of this project:

Professor John Wilkes - Project Advisor

Mr. Brian Cote - Lancaster Eighth Grade Science Teacher

Mrs. Holly Estes - Nashoba Regional School District Curriculum Coordinator

Mr. Peter LaFlemme and Mr. Roger Steele - WPI Reactor Facility

Mrs. Mary Columbo, Ms. Cathy McDunough, Ms. Maura O'Conner, and Mr. Bill O'Grady - Mentorship and support from the Lancaster Middle School Faculty.

Professor Uma Kumar – WPI Chemistry Department

Table of Contents

List of Figures and Tables

Introduction

An investigation of the correlation between increases in one's knowledge and opinion about a controversial public issue was the primary focus of a nuclear technology curriculum unit field test in the Nashoba Public School System. The confluence of previous WPI student projects in this area created a natural "next step forward" in which to integrate existing curriculum revisions, a live role-playing game, and learning style measures into a full scale curriculum unit. The use of surveys developed by prior WPI students allow one to extract both prevailing opinions regarding nuclear technology and the corresponding levels of relevant scientific and technical knowledge. The project will also took advantage of developments in the field of cognitive and learning styles to assess student responses to the unit. The Myers-Briggs Type Indicator (MBTI) will be the primary indicator of learning style in the evaluation phase of the project. Prior curriculum unit evaluation studies have hinted that manipulation of the curriculum structure, namely the degree to which the science content is "socially contexted," (Science/Technology/Society or STS vs. Traditional) has markedly improved the learning of certain student types. These types of learners can be identified using the MBTI, and then assessed for changes in comprehension and retention when their nuclear unit grades are compared to prior evaluations in the yearlong science class.

A feasibility research project was completed in A term of 1999 (September to October) to determine if the existing unit could support a knowledge and opinion study, and whether a research site could by found. The Worcester, Fitchburg, and Nashoba school districts were initially contacted to assess their interest in the project. Worcester was contacted first, but did not respond for some time, so alternate school systems contacts were pursued. Holly Estes, Curriculum Coordinator of the Nashoba Public Schools, responded immediately and favorably to the solicitation. After two meetings, a time line was established and preparatory meetings began with Brian Cote - the Lancaster Middle School eighth grade science teacher whom she thought, quite correctly, would be interested. Implementing the unit in Fitchburg was still also an option, as an eighth grade science teacher from that district had requested a copy of the curriculum. However, following delivery of the unit, there was no further response from the Fitchburg teacher or any other representative of the school system regarding the project. Unofficial inquiries suggested that the teacher noted what he concluded to be a pro-nuclear bias in the unit and just quietly let the matter drop rather than to request revisions or take action through his curriculum office.

My own review of the Harting and Wilkie nuclear curriculum unit IQP revealed many loose ends in terms of usability from the perspective of the educator, as well as a pro-nuclear stance. Given all the additions and revisions being made, it was not difficult to balance the presentation in terms of the debate as well as complete the unit. Despite established lesson plans and learning objectives, the existing unit lacked notes, handouts, quizzes and tests. A comprehensive supplement to the unit was developed in order to deal with these shortcomings, and present a more complete and developed curriculum unit for future teachers to consider using. The details of this supplement are contained in the day-to-day summary of events along with an illustrative compilation of both student and teacher designed homework, projects, and test materials. All of these documents are contained in Part II - Summary of Events.

The relationship between nuclear knowledge and nuclear opinion has been a continuous topic in the nuclear debate, and by extension, science and technology studies. More generally, the nuclear debate maintains a cyclical characteristic, simmering in the peripheries before raging onto center stage with political and ethical undercurrents, and then subsiding back again. Both sides claim to have the support of the "knowledgeable public," and describe the opposition as ignorant, misguided or naïve, and thus to be discounted.

The bleak reality is that a rapidly developing world economy continues to demand more energy. The existing fossil-burning plants have already polluted the earth's natural systems enough to dramatically alter the ecosystem we depend on. Despite previous accidents, some scientists believe that modern nuclear power plants are the key to reversing the trend toward releasing more and more uncontrolled air pollutants that are warming the planet. However, the political realities in expanding democracies demand that the citizens make the decision whether to further develop and deploy nuclear power technology.

Public opinion about nuclear power is volatile. The subject is both controversial and to many, an emotional and symbolic issue about the direction in which technological societies are headed. The merits of nuclear power itself can get lost in the debate about technology and energy consumption more generally. There are also legitimate concerns about the diversion of nuclear fuel to military applications or terrorist organizations.

The “normal” relationship between knowledge and opinion is often described in psychological literature as a process of selective perception, meaning that knowledge will not alter opinion. Some of those studying the public understanding of science and technology feel that technical literacy is a special case. Those who feel that technological literacy is necessary for reasoned decision making about science and technology assume that this kind of knowledge will shape opinion (i.e. change it). The pre-existing literature applied to other subjects suggests the opposite (i.e. only those facts that fit within one's pre-existing opinion will appear to be reasonable, be accepted and retained). Hence, functional knowledge levels will grow, but opinion will not change because of it.

This leads the nuclear energy question to be both a matter of technical and political debate. The fate of the technology really depends on a question beyond what science and engineering can answer. The real question is - "Will the American public approve and support the rejuvenation of the Nation's nuclear industry regardless of whether or not it is the 'right' decision in terms of environmental and efficiency criteria?" Recent trends in nuclear plant construction suggest that the energy industry doubts that public support is present for a resurgence in nuclear power in this nation. While there are still jobs in the field, lack of student interest in nuclear engineering has led to cancelled classes at WPI for years. It is no longer considered a "hot" field with a future and potential for growth. Has the promise and excitement about the computer industry permanently swept away the interest, energy, and resources needed to develop large-scale technology? Is public sentiment about nuclear power irreversible? The experience of the students at Lancaster Middle School doesn't indicate that the prevailing pattern is unchangeable.

The goals of this study are to induce and explore the changes in level of knowledge, and determine how it affects one's nuclear opinion. Understanding their interdependence (or independence) will suggest how opinion, and eventually policy, can be directed in the areas in which technology has profound effects on society. This in turn will provide the basis for conclusions about whether a public technical literacy is necessary – or at least worth striving for.

Quite naturally, the implications of nationwide technical literacy present problems of their own. This study, in conjunction with the knowledge and opinion examination, will investigate alternative techniques in teaching science through the STS approach. The Myers-Briggs Type Indicator will measure the effectiveness of this unit in influencing those students typically disinterested in science. Hence, the implicit capacity of education, through innovative curriculum, to foster a technically literate society will be examined indirectly.

Literature Review

Previous WPI studies have investigated the ongoing nuclear power debate since the mid-1970's. Various northeastern universities and colleges (Bates, Clark, Mount Holyoke, Vassar and WPI) have participated in numerous surveys in an attempt to understand the factors that shape nuclear opinion and fuel the debate.

The knowledge variable has been examined in a number of these studies, as well as risk perception, field of study and political climate. Yet despite roughly a dozen separate data collection efforts in this ongoing project, not one of them has made an attempt to *manipulate* the knowledge variable. These studies have repeatedly gauged the existing level of knowledge and corresponding nuclear opinion in the respondents, and concluded that these variables are independent of one another. Indeed, opinion is most polarized among the most knowledgeable. If anything, it is strength of opinion that is correlated with knowledge about the subject. These types of findings have been derived from non-invasive survey techniques, and are summed up in Shawn Reed's 1997 IQP - *Nuclear Opinion...A Time-Line Study*. (This project was a comparative examination of the nuclear opinion studies completed at WPI since the late 1970's)[1]

1. There is no link between (nuclear) knowledge and nuclear opinion.
2. Personality factors don't affect one's views on nuclear power...
3. The important factor linking one's opinion of the technology and level of confidence all depends on who was considered responsible for controlling nuclear power (i.e. scientists, politicians, etc.)

4. Those who view technology in a negative way are most likely to be anti-nuclear.

Among these studies, almost all have documented notable differences by gender when comparing nuclear opinion. On average, males are 20 percent less likely to be anti-nuclear than females. Gary Torosian's 1991 IQP *Gender and Nuclear Opinion at WPI and Vassar* documents a definitive margin between the sexes, and attributes this stance to typical masculine and feminine gender differences in self-identity. Torosian and Reed conflict in their conclusions regarding the nature of the nuclear knowledge and opinion relationship. Reed's decidedly "no evidence (of correlation)"[2] is countered by Torosian's "some evidence,"[3] and the citing of historical vacillation in previous WPI studies and this contested relationship. The difference depends in part on whether a study used the Bemm Sex Role Inventory to measure "masculinity and femininity" or just reported differences in nuclear opinion by sex. Sex was related to differences in nuclear opinion while Bemm's Masculinity and Femininity sex-role categories were not.

Table 1.1 - Previous Observations in Nuclear Opinion Gender Variance

Study	Male Pro-Nuclear	Male Anti-Nuclear	Female Pro-Nuclear	Female Anti-Nuclear
1997 WPI	50.0	25.0	33.3	42.9
1997 Clark	45.5	36.4	0.0	71.4
1997 Vassar	22.2	55.6	10.8	48.6
1981 WPI/Bates/MHC	51.3	33.3	31.0	42.9
1978 Clark	36.0	52.0	12.0	71.0
Average:	41.0	40.5	17.4	55.4

**Remaining percentage points of each category answered "Unsure/ Do not Know"

**Male minus Female Pro-Nuclear Average: 23.6

**Male minus Female Anti-Nuclear Average: -14.9

Other studies have researched the effect that other variables will have on one's nuclear opinion. Risk perception, confidence in nuclear institutions, and political climate has also been examined for correlation with opinion. The current study also addressed perceptions of science and technology in general as some indicator of opinion. Survey questions were taken from national statistics in *The National Science Board: 1993 Science and Engineering Indicators*, and later compared to the Lancaster findings. Some notable observations made by this national inquiry are described below.

Figure 1.2

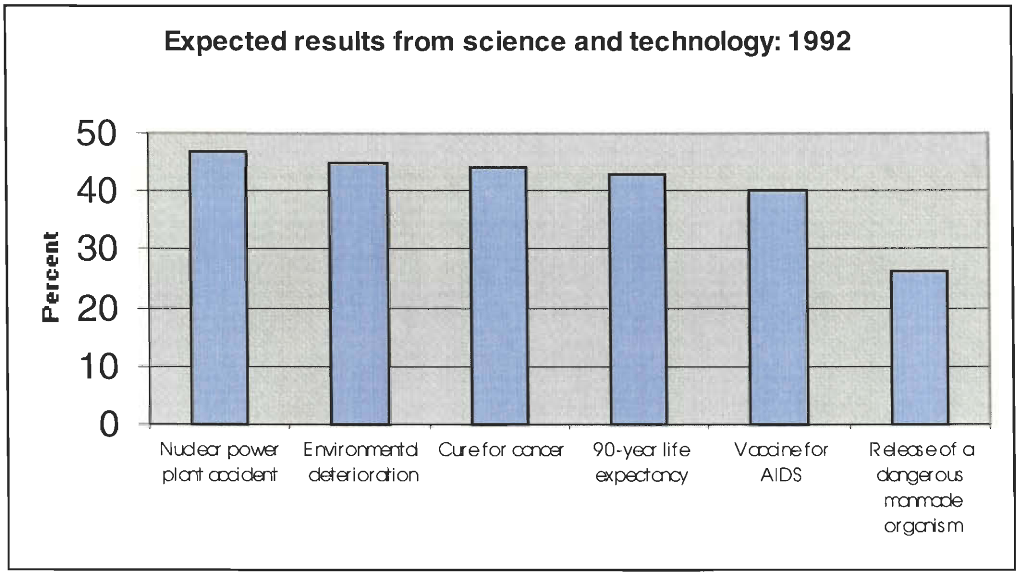
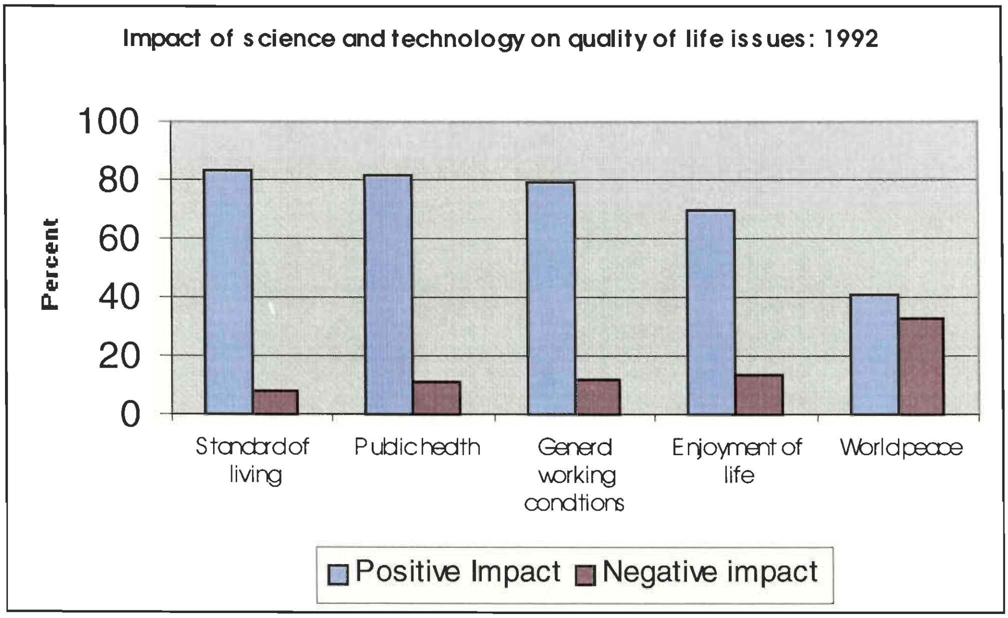


Figure 1.3



In the meantime, a nuclear power curriculum unit had been taken through its third generation of revisions, and was left stranded on the shelves of WPI's Gordon library. The STS (Science/Technology/Society) initiative of the School-College Collaborative is an ongoing project at WPI that fosters the teaching of science through an emphasis on placing science in its social context. The relationship between the technology enabled by scientific advances and the effects on the society it brings about is the justification for the study of science by the average citizen.

With the passing of the tumultuous 20^{th} century, very little is certain concerning the outlook for the next 1000 years. The recent technological changes in our society are almost certainly irreversible, and their rate of progression accelerating. The citizens of the world village must be able to make informed decisions in understanding the both beneficial and problematic changes that a new technology can bring while there is still time to resist its momentum. This kind of public understanding can ensure that we keep tight control over these developments and foster a sustainable rate of growth. Albeit a challenge, the alternative is the catastrophic impact of technology out of control - the Frankenstein nightmare in which man is a service module for a world designed for machines. The goal of STS is to accommodate technology to democracy via technical literacy.

An STS curriculum design requires a less narrow and abstract approach to science through lectures and lab activities. A historical perspective is required to examine the path of technology in the past in search of some clue or model to its possible, even predictable, nature in the future. The goal is to inform social and private choices. The existing curriculum unit was loaded with historical facts stressing the social consequences and significance of various developments as a complement to the science material that typically stands alone in traditional unit designs. As the student becomes aware of some of the more tangible social impacts of technology he or she has been exposed to, the related scientific knowledge becomes "relevant" and increasingly significant. Thus, the "carrot" is hung out to entice a deeper commitment by the student to explore the contents of the science via its social significance. The stimulus is reaffirmed throughout the unit in order to maintain an elevated level of socio-technical inquiry. Robert Yager's study of the capacity for STS to enhance curricula when compared to traditional units in science was completed over three years in conjunction with the National Science Teachers Association (NSTA) and the National Science Foundation (NSF) in 1993. Experts and educators remarked that "the results of this study certainly reflect and provide strong evidence for the high potential of the STS approach."[4]

Past WPI studies have used the MBTI as a learning style indicator and documented the relationship between intuitive type (N rather than S) learners and those who succeed in science studies and are likely to seriously consider it as a career choice. This is due to the capacity of intuitive learners to conceptualize abstract theories and the ability to master the intangible. Quite naturally, it tends to be the intuitive learners who continue the pursuit of science and find careers as scientists, engineers, doctors, and science teachers. This trend has created a significantly larger percentage of intuitive learners within secondary science education, who in turn teach science in the same manner in which they preferred to learn it. The generalist educators who typically teach elementary school science tend to be their cognitive opposites. This notion of continuity among intuitive learners in the fields of science has created an environment of traditional academics. This "science class environment" consists of lecture, demonstration, abstraction, theory and applied mathematics - the same elements "in tune" with the predominantly intuitive teachers. This style of teaching erodes the necessary line of communication with intrinsically sensing and feeling type learners. The successive estrangement of sensing and feeling learners nourishes a growing divide in their capacity to associate with science, and eventually undercuts their future range of choices. They haven't mastered the fundamentals, and consider science "hard" and "uncomfortable," so they opt out of these classes as soon as possible. Later, they must major in other areas for not having taken the prerequisite courses.

The future depends on a technologically literate society that is capable of making these informed decisions. Everyone must be educated at some basic level in science if the world citizens are to make the right decisions. This includes sensing and feeling type learners which are typically one half of the population. If we are to have unilateral technological awareness in the future, it is necessary to begin teaching everyone science today.

WPI's long-standing commitment to STS curriculum development is a reflection of "The WPI Plan." As defined by the 1999-2000 Undergraduate Catalog, The Plan seeks to "replace the traditional rigidly prescribed curriculum - typical of conventional engineering education - with a flexible, exciting, and academically challenging program."[5] The cornerstone to this flexibility is the projects program and Interactive Qualifying Project (IQP) which requires the future technologist to deliver "an issue at the intersection of science, technology, and culture, and emphasizes the need to learn about how technology affects societal values and structures."[6]

The Massachusetts Department of Education had likewise delineated a curriculum framework which included a portion devoted to this topic. Titled "Strand 4," the segment dealt with science, technology, and human affairs, but was rescinded in the Fall of 1999 (after the conception and implementation of this unit field test) under heavy pressure from science teachers who were themselves under pressure to improve statewide standardized test scores (MCAS). They did not see how this social science could be tested fairly, much less rapidly developed in the students. The intention was to free up more time for improving student preparation on relevant test-specific topics. Once it was made clear that the state did not really know how to test for this section yet, it disappeared first from the MCAS test, and then the from the science curriculum standards. Unfortunately, the state has not recognized the relationship of science, technology and society as context and motivation for mastering the more strictly technical material. Hence the curriculum as a whole has been weakened.

Currently, the goal of the STS program at WPI is to continue its implementation and testing in the regional public school systems on the grounds that it teaches science facts and concepts better than conventional units. More importantly, the STS design will reach a wider variety of learning types (as measured by the MBTI), including the sensing and feeling learners that are typically alienated by the presentation of abstract and disconnected science materials. Most students need help to make these socio-technical connections and see applications in their daily lives. Intuitive learners and teachers of science need no prompting to connect them to the surrounding reality to establish their relevance, and favor an abstract brand of learning as "more efficient." This motivation to study science designed for less-scientifically-oriented students who don't find it intrinsically interesting will also preserve a range of future career options, since they will have completed prerequisite courses for advanced studies.

The opportunity to field-test this unit and, for the first time, manipulate the level of nuclear knowledge simultaneously presented themselves to me at the right time for incorporation into this project. By deepening the investigation of the knowledge and opinion correlation, the study would further examine contested areas of the ongoing nuclear debate while enriching the science experience of a group of eighth graders. In effect, the project doubles as both an exploration in opinion shift, and an examination in the effectiveness of a promising STS unit.

In the end it proved to be even more interesting as a historical footnote. In five short weeks, this unit allowed me to transform a group of ill-informed, late 1990's adolescents with a vague anti-nuclear impulse (as indicated by a "pre" opinion survey) into a sharply divided, slightly pro-nuclear population typical of the the US population in the period just prior to the accident at Three Mile Island. Key features of opinion at that time such as gender differences and relationship between nuclear knowledge and opinion shaped by "selective perception" were also evident.

The following analysis sections will begin with a review of findings reported in previous IQP's by WPI students in that period and the next several years. The period, essentially 1977-1989, includes both the Three Mile Island and Chernobyl accident in the United States and former Soviet Union respectively.

Analysis

Knowledge, Opinion and the STS Approach

Preliminary survey results were in line with perceptions of the general public when compared to some national indicators gauged by the National Science Board. This includes assessments of scientific research over time (76% believed that the benefits of research were greater than the harmful affects - see Figure 1.3) and perceptions regarding the safety of operating nuclear power plants. Roughly one half of the student body answered "false" when asked if nuclear power was "safe in general." When polled about what kind of power plant to build in Massachusetts, 45% chose nuclear, while the remaining 55% were divided evenly between coal and oil plants. Interestingly, these statistics regarding support of nuclear power fall into line with previous WPI studies done at Clark, Bates, Vassar and WPI. Even the lesser support for nuclear power among women compared to men was replicated in the Lancaster study. Yet, concurrently with these opinions, the students demonstrated that they knew little about nuclear power technology when tested. On a 0 to 5 composite scale of five knowledge questions in the area of nuclear power, the students scored an average of 1.8.

Knowledge levels would grow over the course of the unit, but would the students' opinions change with the onset of a deeper understanding of nuclear power? The five-week course that would follow was designed to intertwine the historical significance, socioeconomic relevance, and environmental concerns along with the scientific concepts of nuclear technology. In fact, it would be these issues, typically absent in science curricula, which were included in order to stimulate the students to seriously address the science. The intention was to "hook" the interest of the students with attention-getting, historically relevant facts like the efforts of Nazi Germany to build an atomic superweapon, and the 1986 meltdown at Chernobyl. With the stimulus in place (STS unit design), the associated scientific material is taught on a "need-to-know" basis.

The STS design can also implement a variety of other non-traditional education techniques in order to better reach the student. A previous IQP by Schlosser and Volock constructed a live role-playing game (LRPG) in which a town meeting was called in order to settle a nuclear power plant siting dispute. Represented parties included politicians, construction companies, zoning board members, anti-nuclear activists and Nuclear Regulatory Commission members. Each student was given a character sheet that defined a role to carry out for the session, and included descriptions of personality, personal goals, and agenda. A student news team made live, post-meeting reports of the proceedings and videotaped the LRPG.

The primary educational goal of the LRPG was to get students to recall nuclear knowledge and deliver their points to others in support or disapproval of a character's agenda. Secondly, students would teach themselves about the tendency of technology to develop momentum and progress along established lines unless a counterforce is mobilized in the economic or political spheres by interest groups. The variables affecting its direction and pace of development are seldom rational or intentionally associated with the end result. Hence, the importance of understanding social context. Including this type of socially relevant material creates the atypical science experience for most students. It delivers an entire package by tying in the bilateral influences of social goals as they affect technological progress and the resulting human experience. The end result is that the material becomes tangible - tied to a concrete experience - and touches a wider variety of learning types than traditional science units, resulting in greater academic achievement across the board.

A mid-unit knowledge and opinion survey was administered to 25% of the class (prior to the LRPG) in attempt to gauge the flux in those variables caused by just the LRPG and reactor field trip. The survey revealed that knowledge levels in eight out of twelve cases increased from the point after completion of the traditional academic curriculum to completion of the field trip and LRPG. Three out of twelve students stayed at the same level, while only one decreased from this point. This remarkable shift reflects the impact of getting a chance to use one's new knowledge, and "review" the highlights with one's classmates in a game setting. The LRPG and WPI reactor facility field trip were functional learning tools that increased retention and encouraged the students to engage the issue. Similar results turned up in the mid-unit opinion category, in which ten of twelve students expressed a more favorable attitude toward nuclear power after these two STS components. The remaining two students did not shift their opinions during this time frame. This data set strongly supports the notion that that "active" learning in the form of a field trip and LRPG makes a deep impression on the students.

This finding has major implications in their effectiveness as learning tools. Sometimes perceived as "niceties" and rewards for good behavior that dilute the "time on task" of learning the scientific nuts and bolts, the LRPG and field trip experiences proved to be vital components of the academic unit. Both components make strong cases for future implementation in both STS and "traditional" units. Lancaster teacher Brian Cote reflected that "what the students enjoyed the most was the fact that they were able to go to the nuclear power plant at WPI and actually see it up and running. That just gave it a... reality of what they learned in class. Again, they're (a mix of) visual learners as well as concrete learners."[7] Both were well served by the experience.

Interactive demonstrations were also added to the unit in order to broaden the variety of teaching methods used by the curriculum unit. Students enlisted the Internet for project research, as well as the Lancaster library. They used field radiation detection instruments as part of laboratory sessions in exploring radiation and in preparation for the reactor visit. At the reactor facility, students used techniques to minimize radiation exposure, as well as recalling classroom knowledge in order to identify facility components. While it was not like the video clips of Soviet physicists running from "hot spots" encountered while exploring the ruined reactor at Chernobyl, the field trip was exciting to the students nonetheless. The physicists wore the same dosimeters and handled identical Geiger counters as the students had done previously in class. The students knew very well what the purposes of these precautions were. Perhaps in their imaginations, they too were gearing up for a critical mission with large stakes for themselves and their country. Indeed, as they join the ranks of the top 10% of most informed US citizens on the nuclear issue, positioned to be opinion leaders for their generation, they might very well be right about the importance of their mission to explore and observe an operating reactor facility.

Figure 2.1

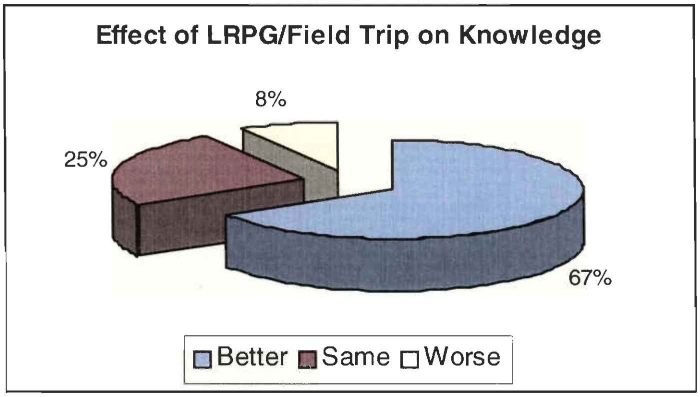
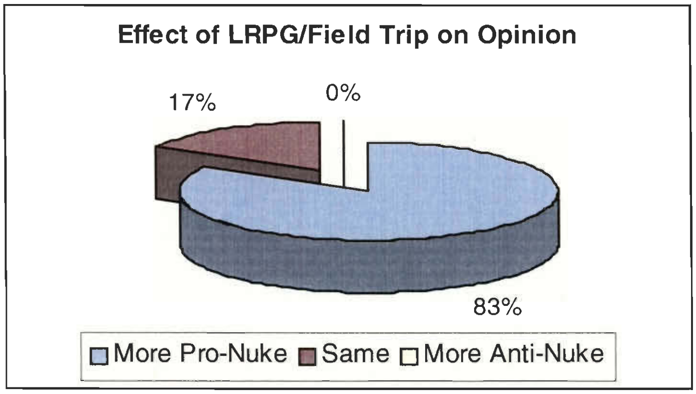


Figure 2.2



The Lancaster eighth grade experienced a seven point mean increase in average science scores during the five-week course when compared to their previous science class grades. This substantial gain is attributed to the implementation of various learning techniques inherently employed by the STS design. When tested using the pre-unit 0 to 5 point scale in nuclear knowledge, the students had raised their level of understanding from 1.8 to 3.2. This gain (78%) in knowledge was accompanied by an even larger (86%) shift in opinion from 2.1 to 3.9 on the same 5-point scale (0 denoting strong anti-nuclear sentiment while 5 represented strong pro-nuclear sentiment). An almost identical change in both knowledge and opinion raises the possibility of a strong relationship between these two factors. Previous research had suggested that no such relationship existed.

Figure 2.3 - Pre and Post-Unit Opinions

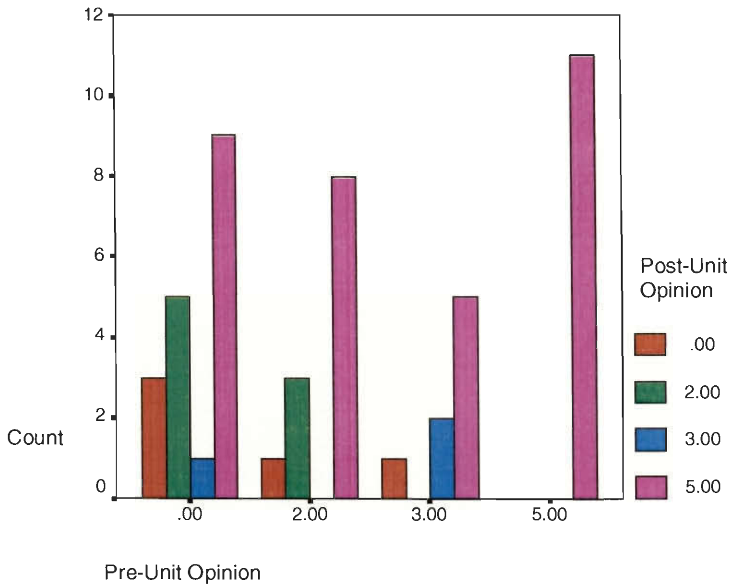


Figure 2.4 – Pre and Post-Unit Observations

Total Number of Students: 63

Pre-Unit Class average: 78.35

Post-Unit Class average: 85.19

Difference: +6.84

Male vs. Female Grade Statistics

Number of Females: 39

Number of Males: 24

Pre-Unit Class Average (F): 78.69

Post-Unit Class Average (F): 82.15

Difference: +3.46

Pre-Unit Class Average (M): 77.79

Post-Unit Class Average (M): 90.13

Difference: +12.33

Knowledge and Opinion Statistics

Pre-Unit nuclear knowledge: 1.79

Post-Unit nuclear knowledge: 3.15

Difference: +1.36 (or 23%)

(0-5 scale where 5 = most nuclear knowledge)

Pre-Unit nuclear opinion: 2.19

Post-Unit nuclear opinion: 3.81

Difference: +1.62 (or 27%)

(0-5 scale where 0 = anti-nuclear and 5 = pro-nuclear)

Male vs. Female Knowledge and Opinion Statistics

Pre-Unit nuclear knowledge (F): 1.63

Post-Unit nuclear knowledge (F): 2.96

Difference: 1.33 (or 22%)

Pre-Unit nuclear opinion (F): 2.04

Post-Unit nuclear opinion (F): 3.70

Difference: 1.66 (or 28%)

Pre-Unit nuclear knowledge (M): 2.00

Post-Unit nuclear knowledge (M): 3.40

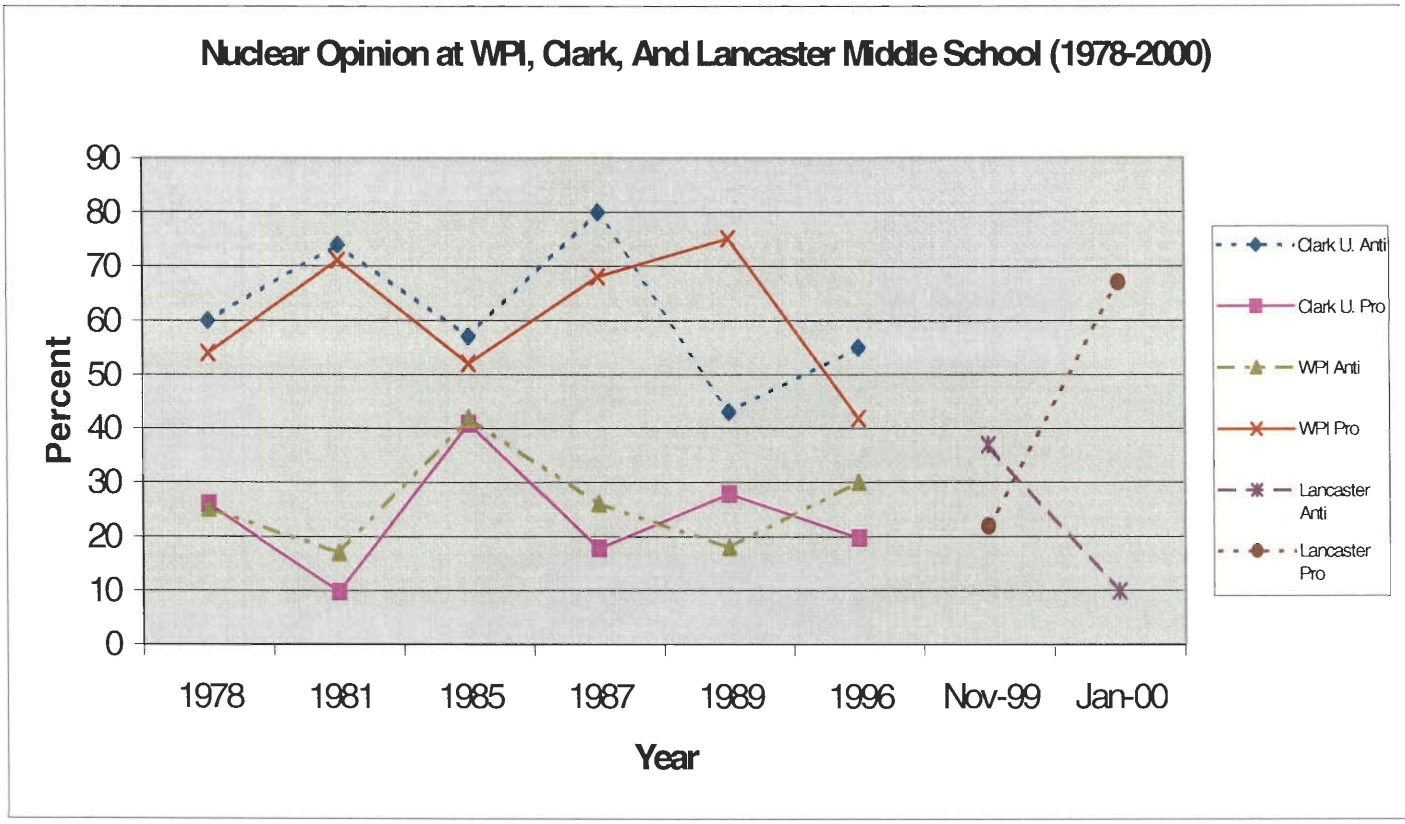
Difference: 1.40 (or 23%)
Pre-Unit nuclear opinion (M): 2.40
Post-Unit nuclear opinion (M): 3.95
Difference: 1.55 (or 26%)

F - M in these categories:

Pre-Unit nuclear knowledge: -0.37 (6%)
Post-Unit nuclear knowledge: -0.44 (7%)
Difference: -0.07 (1%)
Pre-Unit nuclear opinion: -0.36 (6%)
Post-Unit nuclear opinion: -0.25 (4%)
Difference: 0.11 (2%)

Establishing this relationship reflects the necessity for large-scale public awareness programs in nuclear power if it is ever to be entertained as an option in the future. Upon further investigation it was noted that these levels of knowledge coincide with those present in the general public during the late 1970's at the height of the nuclear debate. Presumably, the growth of nuclear power during that decade linked with the accident at the Three Mile Island Nuclear Power Station created an environment in which the populace seemed more concerned with the debate than in present times. The formation of strong opinions is historically linked to maintaining some basic foundation of knowledge within that, or any, subject. Presently the imminent decline of nuclear generating facilities in this country has fostered an apathetic response to the nuclear power option, and subsequently relaxed the level of public awareness. "Within a few years, the closing of aging power plants will eclipse the new plants still coming online, setting the stage for the phaseout of nuclear power."[8] Knowledge levels have dropped to the point that reasoned debate is difficult. It is very interesting that a five week effort was able to reverse that situation and rekindle a debate that resulted in pro-nuclear majority. The boys learned the most and shifted to the strongest pro-nuclear stance, and in the process outperformed the girls for the first time that year.

Figure 2.4



**1979 - Three Mile Island Accident

**1986 - Chernobyl Accident

Gender, Opinion and the T-F (Thinking-Feeling) Dimension of the MBTI

When the median grade increase is broken down, there is a noticeable variance in scores by gender. Further analysis reveals that this difference is closely related to one's pre-unit nuclear safety perceptions. One question in particular that gauged initial perceptions of nuclear safety (before the unit was administered) was closely linked with that student's unit performance as measured by final grade. Roughly 60% of the females did not feel that nuclear power plants were safe before the unit, while only 40% of the males shared that same opinion. Previous national surveys and comparative college population studies (at WPI, Clark, Bates and Vassar) have replicated this finding of a 20% divide between the sexes (women being more opposed on grounds of safety concerns). Of the 15 females that did not feel nuclear power was safe, 13 finished the unit in the bottom 1/2 of the female academic standings. This was also reflected among the males in which 6 of 9 who initially had negative feelings about nuclear power finished in the bottom half of their gender's grade distribution.

The finding that those with unexamined antinuclear opinion predicated on perceived safety problems learned less factual material during the unit is consistent with the theory of selective perception. There is a strong possibility that one's negative connotations about a subject are sufficient to prevent him or her from learning as much about it. This preexisting conviction that there are major reactor safety issues creates cognitive dissonance as the details to this technology and the problems are made known.

As new information is filtered through this personal belief system, one's capacity to absorb new material is limited by the skeptical scrutiny given to discordant data. Some of the new data will be rejected, some considered questionable, and some simply forgotten as "less important and less relevant," due to its dubious nature and questionable source. This condition is described as selective perception. It impacts learning as measured by the retention of facts and results in only partial "mastery" of the new material. The disparity within the unit's academic grade distribution is attributed to the notion that one does not recall the information that falls beyond the boundary of "reasonableness" as defined by his or her prior beliefs. The student rationalizes which material to register, while subconsciously dismissing parts of that which don't fit well within the constraints of previous beliefs or opinions. "The direction of people's guesses or misconceptions will frequently bear a relationship to their attitudes. In a complementary fashion, a given person's knowledge is apt to reflect, in its unevenness, his selective awareness and retention, or his biased sources of information."[9] Within the Lancaster class, the relationship between those that felt strongly against nuclear power at the onset and those that learned the least about it (at the level of facts retained) through the course is unmistakable.

Figure 2.5a – Pre-Unit Perceptions of Nuclear Safety VS. Performance (Male)

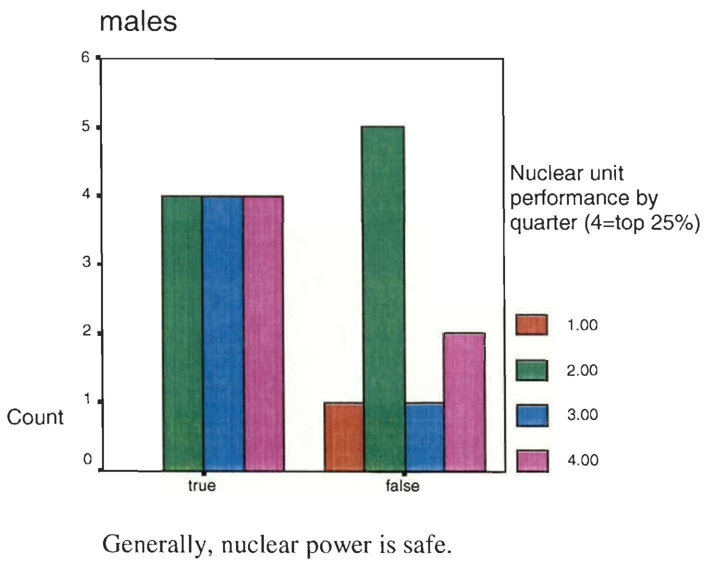
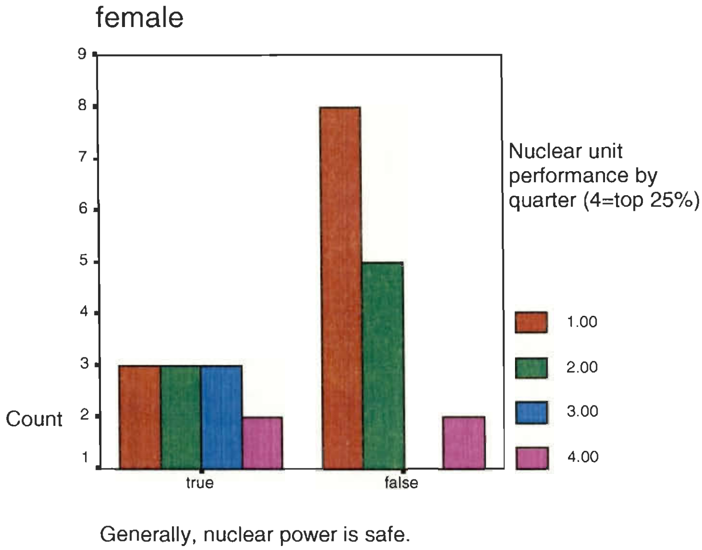


Figure 2.5b – Pre-Unit Perceptions of Nuclear Safety VS. Performance (Female)



However, the dissonance process has "educated" the participating students quite a bit. They may not remember the facts in detail or have taken in the alien logic, but they will know that there is a persuasive counter argument with knowledgeable people that hold opposing views. Of course, what the student wants first is the data that goes along with their case, thus providing them with the ability to defend themselves from their critics, and the reassurance that they were not completely wrong. Later, they may well be able to articulate both sides of the case, and will have learned a great deal despite being less factually informed. The students may not be so adamant or sure of themselves now, but the information they did retain will serve as the foundation for continuing this debate in the future. Perhaps in the future they will be more open to new information given this preliminary lesson in the subject.

The variance in perceptions and opinion between the genders may also be partly due to sex-role socialization. Societal influences, which are particularly strong within this age group, may have contributed to the mixed reception of this complex unit in science and technology. Technology is still a male-dominated area, and female students may have felt reluctant to commit themselves to this unit as fully as they were able to in prior units in the life sciences. Technological aptitude is not normally perceived (in the United States) as an intrinsically feminine virtue. This complex and "dangerous" subject with a historical connection to military weaponry and implications for heavy industry could have been perceived by the female students as less interesting, or even forbidding. Conversely, the males who performed exceptionally well in the unit may have been stimulated by the suggested relationship between the "hard" side of the physical sciences, power, military applications and their association with masculinity - all affecting them in the opposite way. Despite the possibility of sex-role socialization, a variance of this magnitude has seldom been reported in previous WPI studies of this age group. On the other hand, few of the reports discuss gender issues at all - focusing more on learning style diversity.

A deeper examination of the data reveals not only a relationship between gender and pre-unit perceptions of nuclear power (and eventually unit performance), but a relationship between learning type and unit performance. These differences become especially relevant when an emotional and potentially frightening topic like the nuclear power debate is the social context. Evaluation performance data was organized by the Myers-Briggs Type Indicator (MBTI) dimensions, as well as demographics information (like sex). These analysis suggest that "thinking" learners maintained an advantage in incorporating the new information into their opinions over "feeling" learners in this case due to differences in how they approach decision-making. The thinking type learners "are concerned with determining the objective truth in a situation. More impersonal in approach, thinking types believe that they can make the best decisions by removing personal concerns that may lead to biased analyses and decision making."[10] By contrast, the "feeling types are concerned with personal values and with making decisions based on a ranking of greater to lesser importance."[11] Not surprisingly, there was a deep divide between the genders when the students were compared on the T or F variable. Of the 21 total F-type learners, 19 were female, while of the 22 T-type learners, only 6 were female. The correlation between learning type and gender in this sample is quite evident. Is the difference previously reported by sex really a personality difference?

This difference suggests that in a particular case like nuclear power, in which the issues are personal and emotional to many, there exists a divide between learning types. The thinking learners prefer to view the matter in impersonal, and dispassionate terms so as render an objective judgment based on the new material at their disposal. The feeling learners are less bound to judgment based on the evidence, and may not be able to banish lingering doubts based on past perceptions, values and feelings. The feeling learners embrace the symbolic side of the issue, and are most likely to engage the issue at a more subjective level where emotions about this technology and its association with warfare matter. They don't make decisions based on general principles for the good of the majority in the short term - but rather on a case by case basis for the good of all, with even future generations in mind. The first thing they want to know is how the various people involved will be affected. Harmony, not justice or efficiency, is the fundamental goal.

In the Lancaster study, the feeling learners were less able to dismiss their initial perceptions of nuclear safety, and thus absorbed less of the new material being presented than the more "objective and impersonal" thinking learners. There was a strong relationship between the thinking learners and their perception that nuclear power was safe, and conversely, a connection between the feeling learners and those who did not. This in turn affected their grades as reported by Figures 2.6 and 2.7 below.

Figure 2.6 – Perceptions of Nuclear Safety and the T/F Dimension of the MBTI

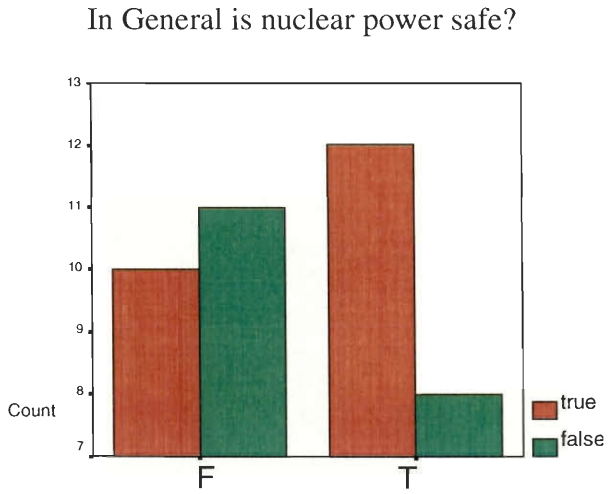
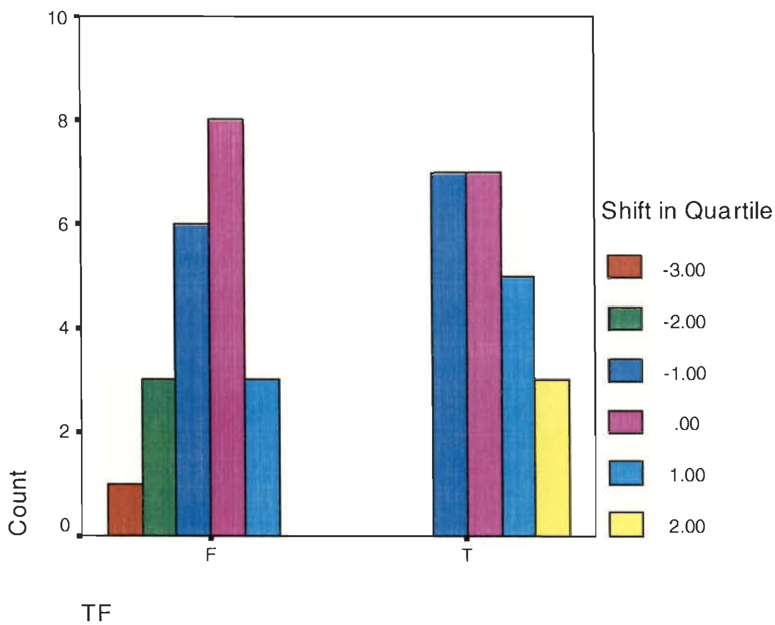


Figure 2.7 – Shift in Class Quartile Standing (before and after nuclear unit) and the T/F Dimension of the MBTI



As mentioned before, the distribution of T and F types was closely associated with gender - the majority of men are T, and the majority of women are F. Typically, the difference is about 2:1 within each sex group. The Lancaster study was a bit extreme in gender, but typical of the general population in its overall distribution of T's and F's (roughly 50/50).

Table 2.8 - Comparison of Lancaster T/F Distribution by Gender and National Average

	T	**F**
National Male	60-70%	30-40%
National Female	30-40%	60-70%
Lancaster Male	89%	11%
Lancaster Female	24%	76%

Despite the likelihood that the aforementioned contributors to the Lancaster improvement cover the important features of the unit as an "intervention" (STS, labs, LRPG, and field trip), it is necessary and equitable to mention some other variables that may have contributed in part to the success of the unit. Perhaps the most important variable not mentioned thus far is the introduction of the students to a topical "expert" in the applicable area of science. Up to this point, there was only one science teacher to be considered for the eighth grade class. Brian Cote is a great teacher and well prepared, but he is not an expert in all fields. Thus, he could only provide the background and technical knowledge at a level consistent with a generalist's understanding of the subject. What the Lancaster class had not experienced to date was the presence of an additional technical expert to provide input, demonstration and laboratory experience, and the necessary background in the specific areas of an applied science. In the case of nuclear power, the class got both. This additional presence of expertise provided an additional variable known to affect nuclear opinion. Many studies have reported that confidence in institutions (ie: trust in the "experts") is associated with support for nuclear power.

Past WPI studies doing pre and post Three Mile Island (TMI) indicated that these variables powerfully interact with knowledge to shape opinion. Some of the best evidence in favor of a selective perception interpretation of the knowledge issue came from two Massachusetts samples of 1000 respondents completed to "bracket" the March 1979 TMI incident in February of 1979 and February of 1980. Those respondents with confidence in business leadership who were most knowledgeable were pro-nuclear, while those who lacked confidence in business leadership and were most knowledgeable were anti-nuclear. Those with less knowledge were less predictable. The relationship worked in reverse for confidence in environmentalists. So, prior attitudes are known to impact the knowledge and opinion relationship in the nuclear power debate to the point of reversing them. One's conceptions of what is credible and what sources to believe are both affected by the "confidence" in institutions variable, which is considered to be a trust in the appropriate experts.

Table 2.9 – The Future of Nuclear Power – A 20-Year Comparison

	Massachusetts Sample of 1000 (3/1980).	Lancaster M.S. 64 8th graders (1/2000)
Use existing & build more	16%	22%
Use existing, but no new starts. Finish those under construction	33%	35%
Use existing, halt construction	25%	16%
Halt construction, shutdown existing	22%	4%
Don't know	4%	20%

Prior evidence of selective perception also came out of the Lovington et al study - a comparison of nuclear opinion at WPI (2/3 pro-nuclear in 1977) and Clark University (2/3 anti-nuclear in 1977). It became clear that while both student bodies had high average confidence in the Scientific Community (which had a modest relationship to one's views of nuclear power), they differed sharply in their confidence of Business leadership and the Government respectively. Clark students tended to be politically liberal and rated leaders of Major Corporation as the least worthy of public trust. Heads of public utilities were likewise rated near the bottom of the scale by the Clark students. By comparison, scientists headed the list of the trustworthy at Clark. Government officials held an intermediate level of confidence on the Clark Campus. WPI students also trusted the scientists the most after they ranked Business leadership as the next most trustworthy with Government much further down the list. Leaders of public utilities were viewed as pseudo business and one step better than Government officials, but of the same ilk.

A distribution of levels of knowledge at both Colleges revealed that the majority of the respondents knew little about the subject, but about 10% were very knowledgeable. The most knowledgeable students at WPI were all pro-nuclear, at Clark all anti-nuclear, and the low knowledge group at each college followed their lead. The minority group opposing the prevailing view scored at medium knowledge levels – enough to beat their average classmates and defend their views, but not enough to match the opinion leaders on campus. On average, their was no relationship between knowledge and opinion. Given a climate of opinion involving a set of attitudes about institutional trust and who is in control of nuclear power technology, the same distribution of nuclear opinion would reoccur at the two Colleges during periodical surveys - even though the entire student body had turned over in the meantime. What made this pattern indicative of selective perception was what happened after TMI and Chernobyl. Starting at 2:1 pro-nuclear at WPI and 2:1 anti-nuclear at Clark (pre-TMI), the WPI student body became more pro-nuclear and Clark more anti-nuclear by 4:1 margins. The polarization based on the same event suggests that the facts can be interpreted in opposite ways given the prevailing assumption and beliefs on each campus. After nuclear opinion converged in 1985 to near parity at the two colleges, the Chernobyl accident reproduced the polarized opinion distributions by campus that had been created by TMI about eight years earlier (see

Figure 2.4). So, the credibility of the knowledgeable, especially the experts, is a critical opinion variable.

The Lancaster students may have reacted more to the presence of a "trustworthy" expert in the classroom, and may have generalized that experience into confidence in the institutions that operate and develop the technology. The opinion shift was not because a "special visitor" advocated for nuclear power – but because he knew it well, and was not afraid that it was too hard to handle safely. Brian Cote remarked that "overall, (I think) all the students were engaged and interested because it was something new…and the fact that we had a professional with a nuclear power background coming in and speaking and demonstrating what actually goes on"[12] was a factor in the success of the unit. Additionally, student interest may have been perked by the "real life" working experience and stories of running a Navy reactor (within the topic of discussion) that the technical advisor was able to offer in the classroom. By now, they knew that the civilian reactors on shore were of the same design for historic reasons.

The introduction and "hands-on" demonstrations performed throughout this project also carried potential for academic improvement in science for the students. A compilation of various learning techniques which included laboratories, demonstrations, field-trip, the Live Role Playing Game, interactive computer software and documentary videos, all within a five week period, conveyed a message of a "new science class" when compared to past experiences in the classroom. This high profile and intensive delivery of new material may have also contributed to the improvement in academic performance among the participants. The students "showed a lot of respect for his (Kaplo's) experience in the field of nuclear energy…but again - this unit wouldn't have had as much success if it wasn't for a teacher that had that background. I (Cote) didn't have that much knowledge or education in nuclear science. I just had the bare bones to teach the elementary chemistry (sections of the unit)."[13]

Lastly, the social or communicative impact of a guest teacher should be considered when attempting to estimate the relative influence of the uncontrolled variables in the evaluation study and graded examination. My personal observation is that there was little difference in character between the existing science teacher and the guest teacher. In this case, both were 26 year-old males who employed similar means of communication with the students. Reaction and acceptance by the students did not vary by any great margin. It is not likely that differences between the two educators as people made any substantial contribution to the mean grade increase experienced by the students during the study. It was much more likely to be curriculum shift than pedagogical style.

Considering the influence that some of these uncontrolled variables may have had on the observed student reactions to the curriculum leads to the possibility of compromise within the results. How much of the grade increase, if any, were these outside variables responsible for? Discussing if there is there any way of eliminating these variables in future studies is probably the most pertinent question. There is no way of interpolating the statistical results in order to pinpoint the effect that the new teacher had on the students' reception of the unit. Unfortunately, this loose end could only be tied down by a continuing nuclear power unit that employed all the STS designs incorporated during the original Lancaster field test with one exception – the "expert" could not be present. Duplicating the findings without the "expert" would guarantee the authenticity of the original findings, and confirm the persuasive case made for science and society curricula.

Despite the inability of this study to isolate the effectiveness of each relevant individual variable, it is illogical to ignore the overwhelming evidence that supports the proven success of the STS design in other studies where the WPI students did not personally deliver the units. Given the fact that these studies have replicated similar mean grade advances when students only advised existing teachers on curriculum without formally lecturing the students themselves, suggests that the persuasion of the "expert" variable is in fact nominal. The personal assessment of the classroom dynamic by Brian Cote would also suggest that the "expert" variable was less important in accounting for the increase in class grades (given the numerous additional efforts to enrich the material).[14]

Conclusion

The Lancaster study maintained two primary goals throughout its course. First was attempting to identify whether there was a correlation between knowledge and opinion. The direct manipulation of the knowledge variable in place of prior, non-invasive, survey-style inquiries would answer what was previously ambiguity and vacillation regarding this correlation. Secondly, the STS approach to teaching science would evaluate its effectiveness when compared to traditional science units.

Perhaps the most surprising finding was the repudiation of conclusions drawn by prior analysts that there was no relationship between level of knowledge and opinion. The implication that "selective perception" theory meant that people would not change their opinion as they became more knowledgeable was disproved. The data from this study implied that (for the majority) the opposite was true, as the class raised its level of nuclear knowledge and corresponding favorable opinions of nuclear power by roughly 75 percent. The 64 students completed this impressive transformation in just five weeks, and drew their conclusions from a comprehensive curriculum that included the history, science, technology, dreams and failures of nuclear power. The shift from an unexamined, anti-nuclear opinion to slightly pro-nuclear is reminiscent of the distribution found in the mid-1970's at the height of the nuclear debate. Even the gender differences noted at that time were replicated in the data.

The process of change in opinion was as revealing as the outcome. Though it is not clear at this time whether the "key" variable was the increase in factual knowledge or "expert trust," the combination of meeting a socially concerned nuclear "expert" and learning about it from him, had a massive impact on public perception and opinion by the end of the course. The stage is set for a litmus test in the future - repeating the course without the presence of an "expert." The unit itself is already neutral, dwelling equally on the promise and the problem – the good news and the bad.

The original STS unit used for this field test was an iteration in the ongoing process by WPI students to create the most effective nuclear science curriculum unit. I added the trappings necessary (handouts, labs, quizzes etc.) to field it as a series of actual lessons. I also included a previous IQP's nuclear power citing dispute live role playing game (LRPG) to the course, and made arrangements for the classes to visit an operating nuclear reactor at the WPI facility. What is interesting is the substantial gain made by the students in factual knowledge through these interactive experiences. Commonly considered embellishments, or even rewards for good behavior, the field trip and LRPG demonstrated their unique ability to challenge the students by requiring them to recall factual knowledge. Traditionally only done by written tests, the LRPG persuaded critical thinking and recalling scientific details in order to support an argument for or against the building of a power plant.

The resulting letter ¾'s of a grade jump in science class performance of the Lancaster eighth grade is attributed to the STS design and the accompanying LRPG and field trip. It is worth noting that not everyone benefited equally in terms of factual gain due to the imbedding of the technical material in the social context of the nuclear debate. The unit-performance divide is not attributed to gender specifically, but to one or more of the following influences: preconceived perceptions of nuclear safety, sex-role socialization, and variance in learning and decision making types (T and F components of the MBTI) correlated with sex in this case. Some of the students could not overcome the barriers to learning the scientific concepts and facts represented by prior perceptions and beliefs incompatible with their views. No anti-nuclear activist was present to help them reconcile this information or use it in an anti-nuclear argument. This was particularly challenging for the females, who tended to make decisions based on feeling (values and social impact) rather than impersonal analysis. Anti-nuclear to begin with, they faced considerable cognitive dissonance that impeded their absorption of the facts. However, the engagement of the thinking types (mostly males), whatever their prior opinion, made for a solid net gain for the class. In prior units, the boys had not been the "stars" in science class. The existence of a "gender divide," although worthy of attention, was not surprising given the wealth of similar findings in previous nuclear studies. This "gender divide" is born from the association of the nuclear debate with war, industry and risk to future generations. As prior studies in STS curricula have demonstrated, the gender disparity was not created by the STS design, but by the intricacies of the social context of the unit.

Perhaps what is most important lies not only in the results of these two inquiries, but in understanding their intrinsic relationship. What is the connection between knowledge, opinion, and how we teach science? The last 100 years has brought enormous changes upon the societies of the world - some good and some bad. The existing rate and momentum of technological advance leaves little doubt in predicting that still greater changes are to come. The future of the planet's environmental health and human sustainability depend on our collective ability to scrutinize the deployment of powerful new technologies, and regulate the progression of existing ones

The expansion of world democracy in the late 20th century is indicative of how world policy will be directed in the near future. The impending need for a technically literate populace becomes evident when examining the process of democratic public policy. If popular knowledge interacts with popular opinion, and eventually controls the legislation and implementation of policy, then the need for public scientific awareness becomes increasingly critical. Fear, ignorance, misinformation, and apathy towards science are all destructive to the postmodern democratic process if we are to foster positive change toward a sustainable and more certain future. Demonstrating that a particular "brand" of curriculum is more successful than traditional units in science in its capacity to reach the full spectrum of learning types has deep implications for creating a technically literate society in the future.

The nuclear knowledge and opinion correlation is a monumental "first step" in understanding the relationship between "what we know" and "what public action will support," and how public opinion will shape the future of possibly the largest single contributor to reduction in air quality and overall environmental health. It is our failure to understand the relationship between our fragile necessities and the decisions which have defined public policy that has perpetuated the confusion and disassociation with our own humanity that is evident in the passing century.

When it is all said and done, the unit should be considered a success simply by the positive experience reported by the students themselves. The endorsement of the STS approach was not surprising, though it was a welcome replication of prior findings. In this case, the strategy of using a controversial technology as the social context had a side effect that reduced test performance in one kind of learner is worth noting as well. The Lancaster Middle School recognizes the value of innovation in education, but most importantly, it was their students who benefited from a stimulating and broadening experience that examined their own past, scientific present, and hopeful future.

Part II - Summary of Events and Academic Unit Supplement

Suggestions and notes from an eighth grade unit field test in the Nashoba School District

Lancaster Middle School

November 16th, 1999 to January 8, 2000

The following summary of events is designed to assist prospective teachers for the nuclear power curriculum. Following each day is the History (HL) or Science Lesson (SL) objective taken from the chapter headings of Revision of Nuclear STS-S Curriculum by Harting and Wilkie (WPI IQP 1997). Personal evaluation of educational benefits and what I might have done differently are included to assist the teacher. Following the summery of events is a compilation of homework assignments, labs, notes, surveys, and tests that were designed by Brian Cote and myself and used during the field test.

Day 1 (HL1)

Introduction and brief overview of the Nuclear Unit. I asked questions like "What would life be like without electricity?" Administration of the Pre-Questionnaire.

HW#1 - Read first 2 pages of Robert Poole's Beyond Engineering - History and Momentum, and answer the first two questions from take-home worksheet.

Day 2 (HL 1)

Discussion of HW#1. Approximately 30 minutes of video - The Soul of Science. This narrated collection of slides provides broad documentation of the technological and scientific achievements from the Greek times to present. I selected a portion that spanned primarily from Edison's light bulb and invention factory to present times. I felt the video demonstrated the tendency of technology to progress incrementally, however its educational value was marginal due to slow moving dialogue and visuals. Some students had a difficult time keeping focused on the information.

HW#2 - Complete Poole's reading and associated question sheet.

Day 3 (HL1/SL1)

Discussion of HW#2 - "The Dream." Comment on the grandiose predictions made by some prominent citizens like H.G. Wells regarding the possibilities of nuclear energy. In general, some people thought it would change our world drastically.

Begin overview of atomic fundamentals in SL1 (Protons, neutrons, electrons, and their relative positions to the nucleus, weight and charge).

Day 4 - 9 (SL1/2)

Each class was divided into thirds. Each group of roughly 6-8 students would spend two days at each "station," and would be responsible for completing work assignments at home. The combined grade for these three "stations" comprised 1/3 of the total unit grade. A breakdown of each station:

Station 1 - Element research. Students were assigned one element from the periodic table and then chaperoned in the library while they researched that element. Students used the Internet and hard copy reference materials to compile information on their assigned element. Upon completing this research, the student prepared a written presentation of the element in a standardized format so that all the elements could be combined to create a large, student-made periodic table on the classroom wall.

Station 2 - Periodic Table & CD ROM. Two groups of 2 students worked on two self-guided science programs on classroom PC's. These programs covered atomic structure as well as fundamentals of the Periodic Table. Blank periodic tables were distributed to the remaining students for them to color-code their table into divisions of metals, non-metals, and metalloids. Solids, liquids and gases were also identified. The groups then switched within this station to complete both tasks.

Station 3 - Molecule Demonstration and Lab. This segment began with a demonstration geared more to charge interaction within the atom itself, and not to inter-atomic (molecular) interactions (bonding). This preliminary demonstration was designed to create a lasting conceptual impression that students would see continually throughout this unit in an easy but fun interactive lab. The students were briefly quizzed on protons, neutrons and electrons, and their respective charges and relative positions to the nucleus. Well, what can be said about charge interaction? I asked the questions - "How do like and unlike charges interact with each other," and "what kind of forces do they exert -

pushing or pulling?" After getting mixed responses, I began the demonstration. Using two simple magnets (the poles were clearly marked positive (+) and negative (-)) I demonstrated that as two unlike charges approached, they pulled on one another (the magnets moved together without my assistance). Conversely, as like charges approached one another, they pushed on each other (the magnets jump away). After having established this concept, I asked "ok, if this is true, and neutron have no charge, then how are all those positively-charged protons packed tightly together inside the nucleus? What should they want to do? (repel - move away from the small nucleus) What's keeping them together?" This is when I introduced the nuclear force, or binding energy, that keeps these repelling particles so close together. I demonstrated this relatively large force by assembling the like ends of the magnets (I added 2 more for a total of 4) tightly together, and holding them in place with my hand. My hand acted as the nuclear force by keeping the like charges together. When I removed my hand, or the nuclear force, the magnets went flying in opposite directions. I described that we would soon learn about the Austrian physicists who fired high speed particles into the nucleus of an atom with the specific intention of releasing that nuclear force in a process called fission.

The molecule lab then continued with an introduction to covalent bonding. A lab handout was used to introduce Lewis structures, atomic shells, and eventually the physical modeling of molecular structures using a ball and stick lab kit borrowed from WPI (Lancaster's kit was missing a few pieces). After practicing on some basic structures with the kits, the group of 6-8 then worked as a team to construct a much larger, more complicated molecule out of colored Styrofoam balls and toothpicks. After completing the assignment, the group was also responsible for making an index card illustrating the molecule's name, chemical symbol, Lewis structure and uses. These index cards were later hung with their Styrofoam models from the ceiling.

At some point during these 6 days I assigned HW#3 - Fundamentals of the Periodic Table, and HW#4 - Fossil Fuels.

Day 10 (HL2/3)

Students gained perspective on the technological development behind nuclear power by completing an in-class chronology. A blank timeline was handed out before lecturing on the major historical events. Each event was marked on the timeline as well as commented in the blanks below.

The students were also introduced to the scope and intensity of the Manhattan Project, as well as identifying its historical stimulus. I felt that this discussion greatly aided in understanding the scope of this technology, and all those events which led up to it.

Day 11 (SL 3)

Perhaps the most intense day of instruction during this project, students are required to build on fundamental scientific concepts to form larger, complex, and more abstract theories.

The lecture began with the same question asked in station three (molecular lab) - "If neutrons have no charge, and protons are all positive, and they exert repelling forces on one another, how do they stay together in the nucleus?" The discussion leads into the nuclear force (binding energy) and eventually into a blackboard demonstration of the fission process that Hans and Strassman discovered in 1939 (meanwhile, Nazi tanks are blitzing through Poland). A neutron is fired into a heavy atom, in this case Uranium, and splits it into smaller fragments, or "fission daughters." Additional neutrons and energy particles (radiation) are released in the process (See figure 1). The two Austrians theorized that it might be possible to sustain this fission in a chain reaction and thereby generating vast amounts of energy.

Alluding to the previous timeline, I again diagrammed on the blackboard what the American physicists accomplished in 1942. A similar fission process generates at least one or more neutrons that go on to strike other Uranium atoms and splitting their nuclei (See figure 2). This chain reaction continues to produce thermal energy.

Once the students felt comfortable with the fission concepts, I introduced them to the idea of controlling the fission process. I asked: "If you need neutrons to start the chain reaction, and they are required to maintain it, what particle do you think the physicists tried to control to control the thermal output of the chain reaction?" Of course, they answered correctly - that neutrons need to be controlled. I then explained that some materials, namely Cadmium and Hafnium (and then pointed to them on the Periodic Table) absorb these neutrons instead of being split by them. Scientists engineered "control rods" out of these metals, and then inserted them into the Uranium blocks to start taking away some of the free neutrons. By inserting them further into the Uranium, they increased the possibility that a neutron would be absorbed and not cause fission - thereby reducing the thermal power of the reaction. Removing the control rods would have the opposite effect.

Day 12-13 (SL4 & 6)

Students completed the Nuclear Energy structured notes packet, while I wrote them out on overhead transparencies.

SCRAM story - I supplemented the definition of SCRAM in the structured notes with an old story I heard from an instructor in Nuclear Power School. The Americans were rushing to complete the A-bomb under heavy pressure . The first chain reaction experiment (see 1942 on the timeline) occurred at the University of Chicago in a squash court underneath the football stadium. Uranium blocks were assembled around neutron absorbing control rods. When all the blocks were in place, the control rod (there was only one) was hoisted out of the core be a rope tied to a pulley overhead. A physicist in the next court pulled on the rope (slowly!) as the others monitored their instruments and looked on. In case the chain reaction began too quickly or got out-of-control, they assigned one of their own with a fire ax to cut the rope if the control rod needed to be inserted quickly. His title was Super Critical Reactor Ax Man (super-critical is when the chain reaction is increasing in speed due to a growing neutron population. A "critical" reaction is self sustaining and a sub-critical reaction is one that is slowing down) or SCRAM. It is the acronym still used in industry today for the immediate insertion of all control rods to shut down the reactor.

Day `14-15 (SL8/9 & HL6/7)

I guided the students through another set of structured notes on radiation principles using overhead transparencies. In this section, students developed perceptions on quantifying radiation, the effects of varying levels of radiation and associated damage to the human body, and finally, radiation levels that are normally present due to background sources. Given this vantage point, students could make their own decisions on how much radiation is "too much."

Day 16 (SL9)

I brought in various pieces of equipment and radioactive sources from the WPI Nuclear Reactor Facility for the students to examine. Among the radiation detection devices were a self-reading pocket dosimeter (something they would be wearing in order to enter the WPI reactor radiation area) and a Geiger-Mueller counter. The Geiger counter was an excellent educational tool in that it allowed students to "see" and measure radiation. Among the sources that students could measure were a household smoke detector (all of which are equipped with radioactive Americium-249), 1950's era Fiestaware dinner plates coated with a Uranium oxide paint, and two controlled radioactive sources: Carbon-14 (frequently used in fossil dating) and Cesium (used in various industrial applications).

I first demonstrated the basic operation of the Geiger counter, and then showed the relative radioactivity of the specimens. Using radiation shielding knowledge from the structured notes, I demonstrated that paper effectively shields beta particles by sliding a sheet of paper in between the detector probe and the beta/gamma emitting C-14 source. When the sheet of paper passed in between the probe and source, measurable radiation dropped of significantly (gamma radiation was still penetrating the sheet of paper while the beta radiation was attenuated).

Following this demonstration, we performed an experiment to prove the logarithmic decay properties of radiation. Placing a ruler next to the source, we were able to measure the radiation at various distances from the surface of the radioactive object, and then examine the results graphically. Although logarithms were mathematically beyond the understanding of the students, they were able to interpret the graph and make critical conclusions regarding the nature and tendencies of radiation (ie:

increasing one unit of distance from the source would reduce radiation levels by a factor of 4).

These experiments provided real-life, hands-on reinforcement of time, distance, and shielding concepts (in order to reduce radiation dose) discussed in the radiation structured note packet.

Day 17

Field trip to WPI Reactor Facility

Permission slips were sent out to the parents in advance in order for the children to attend the field trip to WPI. I detected no parental disapproval regarding the reactor visit from the children or school administrators (all students were present for the trip).

Two school buses departed the Lancaster Middle School at 9:30 and arrived in Worcester at 10:00. Special parking accommodations for the buses were made by the WPI police.

The entire eighth grade class was divided into two groups of 32; with three adults (Two Lancaster teachers and one WPI student or faculty) chaperoning each group. One group went in for the reactor tour while the other was guided through an assortment of other activities on the WPI campus. Upon completing their respective one hour tours, the groups switched venues.

The reactor tour group was broken up into pairs in which one of the two would be given a pocket dosimeter to monitor accumulated dose. Mr. Peter LeFlemme, administrator of the reactor facility, explained the physical components of the reactor while drawing upon some of the theoretical knowledge the students had been exposed to from the curriculum. Students also spoke to technicians and operators who were in the process of bringing the reactor up to the normal operating power level. Once the reactor was above 50% of maximum power, the students filed up to the reactor pool to observe the Cerenkov effect, or the blue glow of the Uranium core, due to radiation properties in water. Once the tour was complete, one of the students was selected to push the SCRAM button at the control panel, while the other students observed the electromagnetic latches release the control rods into the core. The Cerenkov radiation subsided, and reactor power indications dropped to near zero.

The other group met with Mass Academy (11th and 12th graders enrolled in an on-campus high school with a focus on science and technology) students and toured the instructional facility. Lancaster students were accompanied by Mass Academy students and were encouraged to ask questions.

Upon leaving the Mass Academy area, the group was led through three Mechanical Engineering laboratories: Wind Tunnel Fluids lab, Fire Sciences lab, and the SAE racecar MQP area. Interesting differences were observed regarding the students' focus and interaction when the activities were arranged in different chronological order. It was noted that they held their attention more readily when the SAE car lab was last on the list. This is perhaps due to the highly interactive and compelling nature of the imagery that is inherent to the car lab (especially to 13-year-olds!) when the WPI students building it are there and full of enthusiasm as well as willing to let them sit in it. The first group saw this last, and the presenters were able to hold their attention throughout the other activities. The group that did it first was looking for the same level of interaction in the other lab areas. When they didn't find it, they seemed to lose focus quickly.

Day 18

Administration of MBTI

Day 19 (SL8/9)

NOVA Video - Suicide Mission to Chernobyl.

Students completed an in-class worksheet that asked questions about the video. This movie provided critical insight into the nuclear accident in 1986, and provided real footage of the dangerous and sometimes fatal efforts of the Soviet clean-up teams. I felt that the video was well-received by the class. They made connections to the scientists using Geiger counters identical to the ones they had used just a few days before, and were now accustomed to the "expert" radiation terminology used in the documentary.

The footage also provided a powerful anti-nuclear message by exposing the "worst case" catastrophe.

Day 20

Review for unit examination.

Day 21

Administration of unit examination.

Day 22

Preparation for Nuclear Power debate and live role-playing game.

I handed out roles from the Schossler and Vollock version of the live role-playing game (LRPG), and explained that each person would be responsible for representing his or her character during the mock Lancaster town meeting.

Day 23 -24

Videotaped mock Lancaster town meeting.

Day 25

Administration of post-unit opinion survey.

Appendix I – Raw Data

(Microsoft Excel Version 5.0)

#	M/F	Pre-Unit Comp. Grade	Test	Diff. Test	Type	E/I	S/N	T/F	J/P
1	M	82	89	7	INTJ	I	N	T	J
2	F	88	75	-13	ESFJ	E	S	F	J
3	M	85	97	12	ENFP	E	N	F	P
4	M	83	97	14	ENTP	E	N	T	P
5	F	96	98	2	ISFJ	I	S	F	J
6	F	83	74	-9	ESFP	E	S	F	P
7	F	79	86	7	INFP	I	N	F	P
8	M	78	93	15	ESTP	E	S	T	P
9	M	87	94	7	ISTP	I	S	T	P
10	M	76	92	16	ENTP	E	N	T	P
11	F	74	83	9	ENFJ	E	N	F	J
12	F	85	89	4	ESTP	E	S	T	P
13	M	62	89	27	ENTP	E	N	T	P
14	F	50	76	26	ESFJ	E	S	F	J
15	F	91	92	1	ISFP	I	S	F	P
16	F	90	91	1	INTJ	I	N	T	J
17	M	89	98	9	ENFP	E	N	F	P
18	F	77	72	-5	ESFP	E	S	F	P
19	M	80	95	15					
20	M	75	93	18	ESTP	E	S	T	P
21	M	73	86	13					
22	F	81	86	5	ESFP	E	S	F	P
23	M	83	89	6	ENTP	E	N	T	P
24	F	65	86	21	ISTP	I	S	T	P
25	M	87	86	-1	ISTJ	I	S	T	J
26	M	79	82	3	ESTP	E	S	T	P
27	F	75	74	-1					
28	M	57	91	34					
29	F	94	88	-6	ESFP	E	S	F	P
30	F	81	75	-6	ENFJ	E	N	F	J
31	F	87	69	-18	ESFP	E	S	F	P

32	F	84	89	5	ENFJ	E	N	F	J
33	F	100	94	-6	ISFJ	I	S	F	J
34	M	60	85	25	`				
35	F	86	95	9	ENTP	E	N	T	P
36	F	79	57	-22	ENTJ	E	N	T	J
37	M	98	97	-1	ENTJ	E	N	T	J
38	M	81	81	0	ESTJ	E	S	T	J
39	F	95	96	1	ESFP	E	S	F	P
40	F	77	65	-12	ESFP	E	S	F	P
41	M	91	93	2	ENTJ	E	N	T	J
42	F	79	86	7	ENFP	E	N	F	P
43	F	72	72	0	ENFP	E	N	F	P
44	M	77	84	7	ENTP	E	N	T	P
45	F	91	98	7	ESTP	E	S	T	P
46	M	70	70	0	ENTP	E	N	T	P
47	M	79	100	21	ESTP	E	S	T	P
48	F	58	54	-4					
49	F	85	98	13	ENFP	E	N	F	P
Average		80.3	85.7	5.41					

Pre-Unit Survey																		
Student						Perception				Knowledge						Opinion		
14 a	b	c	d	e	WT	17	18	19	WT	24	25	26	29	30	WT	27	28	WT
4	3	4	2	3	4	4	1	1	5	5	2	3	2	5	1	3	1	5
4	4	4	2	2	4	4	1	1	5	4	1	5	1	1	2	3	1	5
4	3	3	2	2	3	3	1	1	4	3	2	2	1	0	3	2	2	0
4	3	4	2	2	3	4	2	1	4	4	1	2	1	1	3	1	1	2
4	4	5	3	3	5	4	1	1	5	0	2	3	1	5	2	0	1	2
4	3	3	3	3	4	5	2	2	2	3	3	4	1	5	2	1	1	2
4	3	3	2	3	3	3	2	1	3	2	2	2	2	2	1	1	2	0
5	5	4	3	3	5	4	1	2	3	4	2	2	1	5	3	3	1	5
5	4	4	2	3	4	5	3	2	1	5	5	5	1	6	1	1	1	2
3	3	4	2	2	3	3	1	1	3	3	2	3	1	6	2	1	2	0
4	3	3	3	2	3	3	2	1	3	4	0	4	1	1	1	3	2	3
4	4	4	2	3	4	4	2	0	3	0	0	0	0	0	0	3	1	5
4	3	4	2	2	3	3	1	2	2	3	2	2	2	5	3	3	1	5
4	2	3	2	3	3	4	1	1	5	4	2	1	1	3	1	3	2	3
4	3	5	3	2	4	3	2	1	3	5	2	5	1	4	1	1	1	2
5	4	4	2	3	4	5	1	1	5	3	2	2	1	2	3	2	1	2
5	5	3	2	3	4	5	1	1	5	4	5	2	1	5	3	3	1	5
4	3	2	2	2	3	4	1	1	5	4	2	3	2	3	0	3	2	3
4	3	3	3	2	3	5	1	1	5	5	2	4	2	3	0	2	2	0
3	3	4	3	3	4	3	2	1	3	3	4	2	1	2	3	3	0	3
5	4	3	2	3	4	4	2	2	2	3	4	2	1	1	3	0	2	0
4	3	5	3	3	4	3	1	2	2	3	2	2	1	1	3	2	2	0
5	4	5	2	3	5	4	1	1	5	1	3	2	2	1	1	2	1	2
4	3	3	2	3	3	4	1	2	3	2	2	2	1	2	2	1	2	0
4	3	4	2	2	3	2	2	1	3	3	2	2	1	1	3	1	1	2
4	3	4	3	2	4	4	0	1	3	5	2	3	1	1	1	2	2	0
5	3	3	3	3	4	4	1	1	5	4	2	5	1	2	1	2	2	0
3	3	3	2	3	3	2	2	2	1	4	3	5	1	1	1	2	1	2
4	4	4	2	3	4	3	2	1	3	2	4	2	1	1	2	3	1	5
5	4	3	2	2	4	3	1	1	4	3	4	3	2	3	1	2	2	0
4	3	3	2	2	3	3	2	0	2	4	2	2	0	3	0	0	2	0
5	3	3	2	3	4	4	1	1	5	2	3	2	2	5	2	3	1	5
5	5	5	3	3	5	4	1	1	5	3	1	2	1	5	5	0	1	2
5	3	4	3	3	4	5	2	1	4	5	4	2	1	5	3	1	2	0
4	4	4	2	3	4	3	1	1	4	3	1	2	2	3	3	2	2	0
4	3	3	2	2	3	3	1	1	4	1	3	2	2	1	1	3	2	0
4	4	4	2	3	4	4	2	1	4	5	2	1	2	5	1	1	1	2
5	4	4	2	0	4	2	1	1	4	2	0	2	1	3	2	2	2	0
4	3	4	1	2	3	4	1	1	5	3	2	2	2	3	2	3	1	5
5	3	5	1	2	4	2	3	2	0	5	5	3	1	5	2	1	1	2
3	3	5	2	2	3	5	2	1	4	3	2	1	2	5	2	3	1	5
5	3	3	3	3	4	2	1	2	2	0	2	0	0	0	0	3	2	3
5	3	3	2	3	4	2	1	1	4	4	4	1	1	1	1	2	2	0
5	3	3	1	2	3	3	2	0	2	3	2	3	1	4	2	3	2	3
3	3	3	2	2	4	3	1	0	2	3	5	2	1	2	3	3	0	3
4	2	1	2	3	2	0	1	2	2	0	0	0	0	0	0	0	2	0
4	3	4	2	2	3	4	1	1	5	3	2	2	2	1	2	3	1	5
4	2	4	2	2	3	4	2	1	4	4	2	4	1	1	1	3	2	3

3	3	4	2	2	3	4	1	1	5	4	2	2	1	0	2	1	2	0
					3.6				3.5						1.8			2.1

Post-Unit Survey																		
Student						Perception				Knowledge					Opinion			
3a	b	c	d	e	WT	17	18	19	WT	25	26	29	30	WT	24	27	28	WT
3	4	4	2	3	4	5	1	1	5	2	2	1	5	4	5	3	1	5
3	3	3	2	2	3	5	1	1	5	2	4	1	5	2	3	3	1	5
5	3	3	2	2	3	3	1	1	4	1	3	1	5	3	2	3	1	5
4	4	4	2	2	4	5	1	1	5	4	3	1	5	2	1	3	1	5
4	4	5	2	2	4	4	2	1	4	2	2	1	5	4	3	3	1	5
4	3	3	2	3	3	4	1	1	5	4	1	1	5	2	3	3	1	5
4	3	3	1	2	3	4	2	1	4	2	2	1	5	4	3	3	1	5
4	5	5	3	3	5	3	1	1	4	1	2	0	5	4	1	3	1	5
4	5	4	2	3	4	4	1	2	3	2	5	1	1	1	5	2	2	0
4	3	4	2	3	4	4	2	2	2	1	2	2	5	4	3	0	0	0
3	3	3	2	3	3	4	1	1	5	5	1	2	5	1	3	3	1	5
4	4	4	2	2	4	3	2	1	3	2	2	1	5	4	3	3	1	5
4	3	3	2	2	3	4	1	1	5	2	2	2	5	3	1	3	1	5
4	2	2	3	3	3	5	1	1	5	2	3	1	5	2	2	3	1	5
5	4	3	2	2	4	3	1	1	4	2	5	1	5	2	5	3	1	5
4	3	4	2	2	3	5	1	1	5	4	2	1	1	3	1	3	1	5
5	4	4	2	3	4	4	2	1	4	1	2	1	5	5	5	3	1	5
4	4	3	2	3	4	3	2	2	1	4	2	1	0	3	2	2	2	0
5	4	3	3	3	4	3	1	1	4	1	3	1	5	3	2	3	1	5
4	3	3	2	3	3	2	2	1	3	5	2	1	5	4	5	3	1	5
5	4	4	2	2	4	5	1	2	3	1	2	1	5	5	3	3	1	5
4	3	3	2	3	3	4	1	1	5	2	2	1	5	4	3	2	1	2
4	4	4	3	3	4	3	2	1	3	4	3	1	5	2	1	3	1	5
4	3	3	2	2	3	3	2	1	3	4	2	1	5	4	3	2	1	2
4	3	4	2	3	4	2	1	2	2	2	2	1	5	4	1	2	1	2
4	3	3	3	2	3	4	1	1	5	2	2	1	5	4	2	3	1	5
4	3	3	2	2	3	4	1	1	5	2	4	1	5	2	5	2	1	2
4	2	2	2	2	2	2	2	2	1	2	4	1	5	2	3	2	1	2
4	4	4	2	2	4	3	2	1	3	2	0	1	5	2	5	3	1	5
4	4	4	2	1	3	5	1	1	5	2	2	1	5	4	4	2	2	0
3	3	3	2	3	3	0	1	1	4	2	2	0	1	2	1	1	2	0
4	3	3	2	3	3	5	3	1	3	2	2	1	5	4	3	3	1	5
5	5	5	3	3	5	5	1	1	5	1	1	2	5	2	1	3	1	5
5	4	5	2	3	5	5	1	1	5	2	2	1	5	4	3	3	1	5
4	4	4	2	2	4	4	1	1	5	4	5	1	5	2	5	3	1	5
4	3	3	2	2	3	2	2	1	3	2	2	1	5	4	5	1	2	2
4	4	5	2	3	4	3	1	1	4	4	3	1	5	2	5	2	1	2
5	4	5	2	2	4	3	1	1	4	2	5	1	5	2	1	3	1	5

5	5	5	2	3	5	5	2	1	4	2	2	1	5	4	3	3	1	5
5	3	3	2	2	3	2	2	1	3	2	2	1	5	4	2	3	1	5
3	3	5	2	2	3	5	1	1	5	1	2	1	5	5	3	3	1	5
3	3	4	2	3	3	2	1	0	2	2	2	1	5	4	3	3	2	3
4	3	3	2	3	3	4	1	0	3	2	2	1	5	4	2	2	1	2
5	4	4	2	2	4	2	2	2	2	2	2	1	5	4	1	3	1	5
3	3	3	2	2	3	2	2	1	3	2	3	1	5	2	2	3	0	3
5	3	3	3	3	4	3	2	1	1	2	2	1	5	4	3	3	2	3
3	3	5	2	2	3	5	1	1	5	1	2	1	5	5	1	3	1	5
4	3	3	2	2	3	4	2	1	4	4	4	1	1	1	4	3	2	5
3	3	4	2	3	3	5	1	1	5	4	2	1	5	4	3	3	1	5
					3.5				3.8					3.2				3.9

Appendix II - Post Unit Interview

Post unit interview with Lancaster's eighth grade science teacher - Brian Cote

1. What was your overall assessment of the nuclear power unit (NPU)?

   Overall, when I first received the unit, after looking at it... it was very weak and did not go along with the state frameworks. And that's just one thing you can't dictate - just the fact that the state framework is changing almost daily in Massachusetts.

*Author's Note: Pre-unit meetings allowed Mr. Cote and I to restructure critical portions of the curriculum in order to reconcile with the State education frameworks. These changes warranted the time allotted for this unit, given that the eighth grade is especially crucial preparatory time for the impending MCAS.

2. What features of the unit design were the most educationally profitable?

   I think what the students enjoyed the most was the fact that they were able to go to the nuclear power plant at WPI and actually see it up and running. That just gave it a...reality of what they learned in class. Again, they're visual learners as well as concrete learners. They saw it, and to me, that was the best part.

3. What features of the unit design were the least educationally profitable?

I think that the part of the design that was least beneficial to the students was the historical parts. They learned... well - history for eighth grade, they just don't see how important it is that the forefathers laid the groundwork for nuclear energy - energy as a whole. I don't know how you can change that because it's no different then US history. They want "right now."

4. In your opinion, were some students more receptive to the unit than others?

   Overall, I think all the students were engaged and interested because it was something new...and the fact that we had a professional with a nuclear power background coming in and speaking and demonstrating what actually goes on. The students that really got more enjoyment out of the unit they had a little more background in their individual skills in nuclear energy, and they tend to be the higher achieving students also.

5. How would you describe the students' receptiveness to the visiting student teacher?

   The students were very enthralled when Mr. Kaplo spoke, and they showed a lot of respect for his experience in the field of nuclear energy...but again - this unit wouldn't have had as much success if it wasn't for a teacher that had that background. I didn't have that much knowledge or education in nuclear science. I just had the bare bones to teach the elementary chemistry.

6. In your opinion did the nuclear power unit attempt to persuade opinion in one direction or the other?

Absolutely not. I think the unit touched upon the positive and negative aspects of nuclear energy. But it also depends on the people presenting the unit, and their ideology of nuclear energy. That could dictate how the unit comes across. We certainly always emphasized the negative aspects and positive aspects of nuclear energy.

7. Comment on the nuclear power siting dispute live role-playing game.

The LRPG is crucial to the ending of the unit. It shows a real-life debate. One thing that I can say is that the students as whole need to... well it should be much more than just a day of doing this role playing game. It takes a lot of practice for this to come off to be the way the instructors want it to be. The students need to have a good understanding of parliamentary procedure.

8. Comment on the WPI reactor facility field trip.

The field trip was certainly a success in my eyes. The students came back and were really energized by what they saw. Some weren't, but again we did touch upon the whole (radiation) dose...and when you talk about nuclear energy and nuclear science, some people do become scared. The students weren't really that apprehensive about going in because of the knowledge that they had gained prior to that. That was something we gave to them.

9. How confident are you that the nuclear power unit could stand alone without a visiting technical advisor?

If the unit was brought into a school without a visiting instructor, I would say it would be a failure. Now that I was in the classroom and have the knowledge of the unit, I feel that I could do a fairly decent job presenting to the students next year, but still, I don't think it would come across as well without that instructor.

10. Will you administer the unit again in the future? If so, would you do anything differently?

I certainly plan to use it again… there are aspects that I will change just for the fact that time frame wise. There is so much that the students in eighth grade need to get throughout the school year, that you just can't take that much time on learning one topic. When we did this, we condensed it and combined other aspects of the curriculum that the students needed to know. Again, length is now an issue because I'm crunched for time.

Nuclear Technology Unit Eighth Grade Pre-Questionnaire

1. What is your name? ______________________________

2. What is your native language? (English, Spanish, French, etc.) ______________

3. Are you (check one)

   a) Male ____________ b) Female ____________

4. Do you live (check the one that most closely fits)

   a) in a city ____ b) near a city (suburbs) ____ c) in a rural area ____

5. What is your age? ____________

6. Do you have brothers and sisters? (check one) Yes______ No ______

7. What are your favorite hobbies? ______________________________

8. What is your father's occupation? ______________________________

9. What is your mother's occupation? ______________________________

10. What do you expect to be when you are their age? ______________________

11. Are you planning to go to college in the future? Yes ______ No ______

12. During an average week, how much time do you do things that involve science?

    ____

13. Which of the following pairs of classes do you generally prefer?

    Please circle the one you prefer.

    a) Life Science (Biology) OR Physical Science (Chemistry)

    b) English OR Science

    c) Math OR Science

    d) Social Studies OR Science

    e) Music OR Science

14. Regarding this science class, (circle one)

a) How much effort would you need to put into this class in order to get an A?

none at all	not much	about average	quite a bit	very much
1	2	3	4	5

b) How much effort are you putting into this class right now?

none at all	not much	about average	quite a bit	very much
1	2	3	4	5

c) Do you expect to do well in this class?

not very well	below average	average	above average	very well
1	2	3	4	5

d) How important will the information you learn in this class be to your life after you graduate from High School?

not at all important	somewhat important	very important
1	2	3

e) How important will the information you learn be to your future schoolwork?

not at all important	somewhat important	very important
1	2	3

15. If it were up to you, would you spend more or less time studying science in school?

Much less time	less time	about the same	more time	much more time
1	2	3	4	5

16. Do engineers have a responsibility to think about the environment as they develop new things? (check one)

Yes__________ Maybe_________ No___________

17. In the real world, engineers consider the impact their work will have on the environment.

never	rarely	sometimes	frequently	always
1	2	3	4	5

18. In general, most scientists want to work on things that will make my life better.

Always__________ Sometimes___________ Never_____________

19. Checkmark the one you feel is most correct.

______ a) Benefits of scientific research are greater then the harmful results.

______ b) Harmful results of scientific research are greater then benefits.

20. How much confidence do you have in the following organizations? (Circle One)

	A great deal of confidence	some	hardly any	none
a. The President of the U.S.	1	2	3	4
b. U.S. Supreme Court Justices	1	2	3	4
c. Members of the U.S. Congress	1	2	3	4
d. Leading newspaper journalists	1	2	3	4
e. Presidents of large companies	1	2	3	4
f. Leading Scientists	1	2	3	4
g. TV news team achorperson	1	2	3	4
h. Leaders of environmental groups	1	2	3	4
i. Well known teachers & professors	1	2	3	4
j. High ranking Military Officers	1	2	3	4

21. How important are the contributions of each of the following professional groups?

	very important	only some	a little	none at all
a. Musicians	1	2	3	4
b. Educators	1	2	3	4
c. Engineers	1	2	3	4
d. Writers	1	2	3	4
e. Artists	1	2	3	4
f. Historians	1	2	3	4
g. Psychologists	1	2	3	4
h. Economists	1	2	3	4
i. Politicians	1	2	3	4
j. Scientists	1	2	3	4

22. Circle the best choice that describes your view of science:

Science is:

a) Interesting but not important

b) Important but not interesting

c) Important and interesting

d) Not important and not interesting

23. Please circle the number that most closely represents how much you agree or disagree with the statement.

a. Science helps me how to think more clearly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

b. Math helps me how to think more clearly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

c. Technology gets out of control, and lots of people are hurt directly or indirectly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

d. The Scientific Community can solve any problem given enough time and money.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

24. In the United States, we operate about how many nuclear reactors? (check one)

None_____ 5-10______ 25-100 ______ 100-500_____ Over 1000______

25. Nuclear Power was first developed in what country?

United States____ Russia______ Japan____ Germany____ England_____

26. In the United Sates, we have had how many nuclear accidents?

None_____ 1-5______ 5-10_______ 10-25_______ Over 100_______

27. If we needed to build another power plant in Massachusetts, I would prefer a: (circle one)

Coal Plant Oil Plant Nuclear Plant

28. Generally, nuclear power is safe. True______ False_______

29. In Massachusetts, we have nuclear power plants. True_______ False________

30. Nuclear power plants produce energy by a process called (check one):

______Fusion ______Photosynthesis

______Oxidation ______Fission

______Combustion ______Dehydrogeneration

31. In your own words, describe how you think a nuclear power plant might work, and/or describe anything else you might understand about nuclear power

____

____

____

____

____

____

____

____

____

Nuclear Technology Unit Eighth Grade Mid-Questionnaire

1. What is your name? ______________________________

2. Do engineers have a responsibility to think about the environment as they develop new things? (check one)

   Yes__________ Maybe_________ No___________

3. In the real world, engineers consider the impact their work will have on the environment.

never	rarely	sometimes	frequently	always
1	2	3	4	5

4. In general, most scientists want to work on things that will make my life better.

   Always__________ Sometimes___________ Never_____________

5. Checkmark the one you feel is most correct.

   ______ a) Benefits of scientific research are greater then the harmful results.

   ______ b) Harmful results of scientific research are greater then benefits.

6. Circle the best choice that describes your view of science:

   Science is:

   a) Interesting but not important
   b) Important but not interesting
   c) Important and interesting
   d) Not important and not interesting

7. In the United States, we operate about how many nuclear reactors? (check one)

   None_____ 5-10______ 25-100 ______ 100-500_____ Over 1000______

8. Nuclear Power was first developed in what country?

United States____ Russia_____ Japan____ Germany____ England_____

9. In the United Sates, we have had how many nuclear accidents?

None_____ 1-5______ 5-10_______ 10-25_______ Over 100_______

10. If we needed to build another power plant in Massachusetts, I would prefer a: (circle one)

Coal Plant Oil Plant Nuclear Plant

11. From everything you know, how safe do you think nuclear power is?

_____ 1) Very Safe

_____ 2) Safe

_____ 3) Hazardous

_____ 4) Very hazardous

_____ 5) Unsure

_____ 6) Do not care

12. In Massachusetts, we have nuclear power plants. True_______ False________

13. Nuclear power plants produce energy by a process called (check one):

______Fusion

______Oxidation

______Combustion

______Photosynthesis

______Fission

______Dehydrogeneration

14. How do you feel about building a nuclear power plant within 10 miles of Lancaster, MA?

_____ 1) Strongly favor

_____ 2) Favor

_____ 3) Oppose

_____ 4) Strongly oppose

_____ 5) Unsure

_____ 6) Do not care

Nuclear Technology Unit Eighth Grade Post-Questionnaire

1. What is your name? ____

2. Which of the following pairs of classes do you generally prefer?

   Please circle the one you prefer.

a) Life Science (Biology)	OR	Physical Science (Chemistry)
b) English	OR	Science
c) Math	OR	Science
d) Social Studies	OR	Science
e) Music	OR	Science0

3. Regarding this science class, (circle one)

   a) How much effort would you need to put into this class in order to get an A?

none at all	not much	about average	quite a bit	very much
1	2	3	4	5

   b) How much effort are you putting into this class right now?

none at all	not much	about average	quite a bit	very much
1	2	3	4	5

   c) Do you expect to do well in this class?

not very well	below average	average	above average	very well
1	2	3	4	5

   d) How important will the information you learn in this class be to your life after you graduate from High School?

not at all important	somewhat important	very important
1	2	3

   e) How important will the information you learn be to your future schoolwork?

not at all important	somewhat important	very important
1	2	3

15. If it were up to you, would you spend more or less time studying science in school?

Much less time	less time	about the same	more time	much more time
1	2	3	4	5

16. Do engineers have a responsibility to think about the environment as they develop new things? (check one)

Yes__________ Maybe_________ No___________

17. In the real world, engineers consider the impact their work will have on the environment.

never	rarely	sometimes	frequently	always
1	2	3	4	5

18. In general, most scientists want to work on things that will make my life better.

Always__________ Sometimes___________ Never_____________

19. Checkmark the one you feel is most correct.

______ a) Benefits of scientific research are greater then the harmful results.

______ b) Harmful results of scientific research are greater then benefits.

20. How much confidence do you have in the following organizations? (Circle One)

	A great deal of confidence	some	hardly any	none
a. The President of the U.S.	1	2	3	4
b. U.S. Supreme Court Justices	1	2	3	4
c. Members of the U.S. Congress	1	2	3	4
d. Leading newspaper journalists	1	2	3	4
e. Presidents of large companies	1	2	3	4
f. Leading scientists	1	2	3	4
g. TV news team anchorperson	1	2	3	4
h. Leaders of environmental groups	1	2	3	4
i. Well known teachers & professors	1	2	3	4
j. High ranking military officers	1	2	3	4

21. How important are the contributions of each of the following professional groups?

	very important	only some	a little	none at all
a. Musicians	1	2	3	4
b. Educators	1	2	3	4
c. Engineers	1	2	3	4
d. Writers	1	2	3	4
e. Artists	1	2	3	4
f. Historians	1	2	3	4
g. Psychologists	1	2	3	4
h. Economists	1	2	3	4
i. Politicians	1	2	3	4
j. Scientists	1	2	3	4

22. Circle the best choice that describes your view of science:

Science is:

a) Interesting but not important

b) Important but not interesting

c) Important and interesting

d) Not important and not interesting

23. Please circle the number that most closely represents how much you agree or disagree with the statement.

a. Science helps me how to think more clearly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

b. Math helps me how to think more clearly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

c. Technology gets out of control, and lots of people are hurt directly or indirectly.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

d. The Scientific Community can solve any problem given enough time and money.

Strongly agree	agree	disagree	strongly disagree
1	2	3	4

24. In the United States, there are about 80 nuclear reactors and another 80 under construction. What should be done with those plants?

____ 1. Continue those already built, finish those under construction and build more.

____ 2. Continue those already built, and stop construction on the others.

____ 3. Finish the plants under construction, but build no more.

____ 4. Shut down all nuclear power plants as soon as possible.

____ 5. Unsure / Do not care – let the experts decide.

25. Nuclear Power was first developed in what country?

United States____ Russia_____ Japan____ Germany____ England_____

26. In the United Sates, we have had how many nuclear accidents?

None_____ 1-5______ 5-10_______ 10-25_______ Over 100_______

27. If we needed to build another power plant in Massachusetts, I would prefer a: (circle one)

Coal Plant Oil Plant Nuclear Plant

28. Generally, nuclear power is safe. True______ False_______

29. In Massachusetts, we have nuclear power plants. True_______ False________

30. Nuclear power plants produce energy by a process called (check one):

______Fusion ______Photosynthesis

______Oxidation ______Fission

______Combustion ______Dehydrogeneration

Science Class
Mr. Cote
Assignment for 11/18/99

Name:____

1. What were some ways people could illuminate a dark room before Edison's light bulb in 1879?

2. How did visitors react to the light bulb from their visit to Menlo Park?

3. What did scientists like Rutherford and Soddy say about the amount of energy released from atomic change when compared to other chemical types of change (ie: coal, oil...)

4. How did the writers like H.G. Wells and David Dietz respond to the discovery of nuclear energy?

5. What sort of problems to developing nuclear power happened next?

Covalent Molecules

1 lab period; work in pairs. Complete the Preparation page before laboratory.

Goals

- To enable you to predict and visualize molecular shapes

Background

The three-dimensional arrangement of atoms in a molecule--its shape--determines virtually all of the properties of not only the molecule, but of the substance that it represents. Thus the shape adopted by the molecules of a substance determines the melting and boiling points, solubility, strength, and reactivity of the substance.

Molecular shape is a consequence of the distribution of electrons in a molecule. It would seem to be a difficult matter to predict the distribution of electrons, and indeed to do so precisely requires sophisticated experimental and theoretical methods. However, it turns out to be quite simple to predict qualitatively how the electrons in a molecule will be arranged using a simple idea called the Valence Shell Electron Pair Repulsion Theory (VSEPR). The essential idea of the theory is that *electron groups in the valence shell of an atom distribute to minimize repulsions between them.* An electron group is any of the following things:

- a nonbonding electron pair
- a single bond
- a double bond
- a triple bond
- a single electron (rare)

To apply VSEPR requires only that we be able to generate a valid Lewis structure for the molecule, which is simple to do. Once the Lewis structure is available, the electron groups can be counted, and the distribution of groups about any chosen atom can be predicted using Table 1.

Total Number of Groups	Group Distribution	Number of Groups with Attached Atoms	Shape
2	linear	2	linear
3	trigonal planar	3	trigonal planar
		2	bent
4	tetrahedral	4	tetrahedral
		3	trigonal pyramidal
		2	bent
5	trigonal bipyramidal	5	trigonal bipyramidal

		4	see-saw
		3	T
		2	linear
6	octahedral	6	octahedral
		5	square pyramid
		4	square plane

The purpose of this workshop is to familiarize you with the relatively limited number of molecular shapes by giving you an opportunity to build models.

Focus Questions

Focus Questions are included in the Experimental Procedure, below.

Equipment and Materials

A good commercial molecular model kit capable of simulating molecules in which the central atom has up to six electron groups.

Experimental

Two guidelines in building structures:

- First, the ball representing the central atom must have a number of holes consistent with the number and nature of electron groups around the central atom in the Lewis structure. For example
  - If the Lewis structure shows 4 electron groups consisting of 3 single bonds and 1 lone pair, the central atom ball must have 4 holes;
  - If the Lewis structure shows 3 electron groups consisting of 2 single bonds and 1 double bond, the central atom ball must have 4 holes, because 2 holes will be used to make the double bond
- Second, you should explicitly represent lone pairs in your models using short, fat grey sticks, usually used for single bonds.

Activities

1. Develop Lewis structures for CH_4, NH_3, and H_2O; then build models for them. (Remember that you must explicitly put the lone electron pairs on oxygen in the water molecule!) Make a stereochemical drawing of each molecule
   - Are these molecules isoelectronic?
   - Are they isostructural?
   - Describe the electron group distribution in each molecule.
   - Describe the shape of each molecule.
   - Predict the H-X-H bond angle for each molecule.

2. Draw a Lewis structure for ozone, O_3. Build a model, and make a stereochemical drawing.

- Describe the electron group distribution in ozone.
- Describe the shape of ozone.
- What is the bond angle in ozone?
- Based on your model, what would you predict about oxygen-oxygen bond lengths in ozone?
- Experimentally, it is found that the oxygen-oxygen bond lengths in ozone are identical. How can this be explained?

3. Benzene consists of a ring of 6 carbon atoms, with one hydrogen atom bonded to each carbon. Draw the Lewis structure for benzene. Build a model.
   - What is the stereochemistry at each carbon atom?
   - Is benzene a flat (planar) molecule? Explain.
   - Based on your model, what would you predict about carbon-carbon bond lengths in benzene? About C-C-C and H-C-C bond angles? (C-C bonds have length of about 0.154 nm; C=C bonds have length about 0.133 nm.)
   - Experimentally, benzene is found to have all carbon-carbon bond lengths the same at 0.139 nm. Explain.

4. Develop Lewis structures for
   - BF_3
   - CH_2O
   - C_2H_4
   - $C_2H_2Cl_2$ (put one H and one Cl on each C)
   - N_2O_4

   For each molecule, build a molecular model based on the count of electron groups on the central atom(s). For each molecule, determine the following:
   - Central atom electron group distribution
   - Molecular shape
   - Values of the X-A-X and X-A-A (last 4 molecules only) bond angles (X = terminal atom, A = central atom(s))
   - Whether of not resonance forms are appropriate. If they are, draw them
   - The A-X and A-A (where relevant) bond orders (bond order is the number of bonds between a pair of atoms)
   - Whether the molecule is planar
   - Whether there is more than one way to build $C_2H_2Cl_2$.
   - Whether the molecule is polar. In what direction does the molecular dipole point? (Answer this question at the discretion of the instructor.)

5. Develop Lewis structures for
   - PF_5
   - IF_5
   - SF_4
   - XeF_4
   - ClF_3
   - XeF_2

For each molecule, build a molecular model based on the count of electron groups on the central atom(s). For each molecule, determine the following:

- Central atom electron group distribution
- Molecular shape
- Values of the X-A-X bond angles (X = terminal atom, A = central atom(s))
- Are all F atoms in PF_5 the same? If not, label the different categories on your drawing.
- Are all F atoms in SF_6 the same? How about in IF_5?
- Whether the molecule is planar.
- Whether the molecule is polar. In what direction does the molecular dipole point? (Answer this at the discretion of the insructor.)

6. Join another group and pool your kits. Build a model of the dipeptide of alanine and leucine, amino acids with these structures. Discuss in writing the stereochemistry at each atom in the main dipeptide chain.

Clean-up. When you have finished all of your work, return all model pieces to the box, count each type to make sure all pieces are present, and return the kit to the instructor before leaving the lab.

Molecularity: Covalent Molecules Preparation

Click here to access Preparation Questions.

Exploration of Elements and The Periodic Table

Step I: Ball and Stick Configuration

- Worked throughout class cooperatively with group members 1 2 3 4 5
- Model of molecular compound has a description which is typed or printed. Description includes: name of compound, use for the compound, and the number of atoms for each element. 1 2 3 4 5

Stage 2: Research of Element

- Worked throughout class cooperatively with no distraction 1 2 3 4 5
- Research of element includes: element name, symbol, atomic number, atomic weight, melting point, and boiling point. 1 2 3 4 5
- 2-3 uses of the element in the world today. 1 2 3 4 5
- Findings from research are typed or printed on paper (more creative and colorful the better score). 1 2 3 4 5
- Notes of research are passed in along with final copy. 1 5

Stage 3: CD-ROM Exploration and Color Coding

- Worked cooperatively throughout period and partners explored equally with the computer. 1 2 3 4 5
- Worksheets are passed in at the end of the period complete. 1 2 3 4 5
- Notes on the atom including: nucleus, protons, neutrons, and electrons are passed. 1 2 3 4 5
- Blank copy of Periodic Table is color coded, dividing the metals, non-metals, and metalloids. 1 2 3 4 5
- Chart is filled in with all the elements that Mr. Cote wants us to know. 1 2 3 4 5

- Overall of appearance of work and effort. 1 2 3 4 5

Science Class
Mr. Cote
Homework

Name:____________________________________ **Date:**_______________

Directions: Answer the following questions using your Periodic Table of the elements.

1. How many protons are there in one atom of Helium? ______________

2. What is the magnetic charge of an electron? _____________

3. What is the atomic weight, in AMU's, of one atom of sodium? ________________

4. Name the atomic symbols of the following elements (ie: Oxygen = O).

   Hydrogen: _________ Lithium: ____________

   Chlorine: __________ Argon: _____________

   Mercury: __________ Copper: _____________

5. In degrees Celsius, what is the melting point of Magnesium? ____________

6. Give the symbol and then decide if the following elements are metals, metalloid or non-metals. Then write down its physical state: solid, liquid or a gas.

Element	Symbol	Metal/Metalloid/Non-metal	Physical State
Boron			
Mercury			
Nitrogen			
Potassium			
Carbon			

NAME DATE CLASS

Chapter 25

REINFORCEMENT

Use with Text Pages 700

Fossil Fuels

Complete the table below by placing a check mark (√) beneath the headings of the substances that have each charac istic described in the first column.

Characteristic	Petroleum	Natural Gas	Coal
1. is a fossil fuel			
2. forms from plants and animals			
3. forms only from plants			
4. is a solid			
5. is a liquid			
6. is a gas			
7. is made up of hydrocarbons			
8. is a source of energy			
9. is a nonrenewable resource			
10. is pumped from wells			
11. is separated using fractional distillation			
12. is also called crude oil			
13. is transported long distances through pipes			
14. is mined from Earth			
15. produces polluting substances when burned			
16. produces thermal energy when burned			
17. can be used to produce electricity			
18. is the least polluting fossil fuel			

Eighth Grade Science - Nuclear Energy
Structured Notes and Study Guide

Name: ____

I. The Fission Process

An atom consists of a nucleus containing protons (+ charge) and neutrons (______ charge). Surrounding the nucleus are ________ which have (______ charge), which fly in orbits around the nucleus at the speed of ________.

Because the protons are all of positive charge, they exert a _______ force on one another. It is the __________ energy, or " __________ force" that keeps them together.

In 1939, Austrian scientists split the first atom. This process called _________ , released the nuclear force that once bound the nucleus together. This release of ________ energy was unprecedented in magnitude.

Fission : ____

____

Draw the Fission Reaction:

Each time a fission occurs, energy is released in the form of ______________.

Contolling the number of __________ that are travelling in the core will control the number of _________________. This controls the amount of heat the reactor generates.

II. The Reactor

How is the neutron population controlled?

By inserting __________ - absorbing __________________ into the core. To increase power (increase the number of fissions ---> more heat) you would ____________________________. To reduce power, you would ____________________________.

What is a reactor SCRAM?____
____

Make a simple drawing of a nuclear reactor:

Control rods are frequently made out of ____________ or ______________.

The pressure vessel is made out of _______________.

Define the following components located in a reactor:
Moderator -

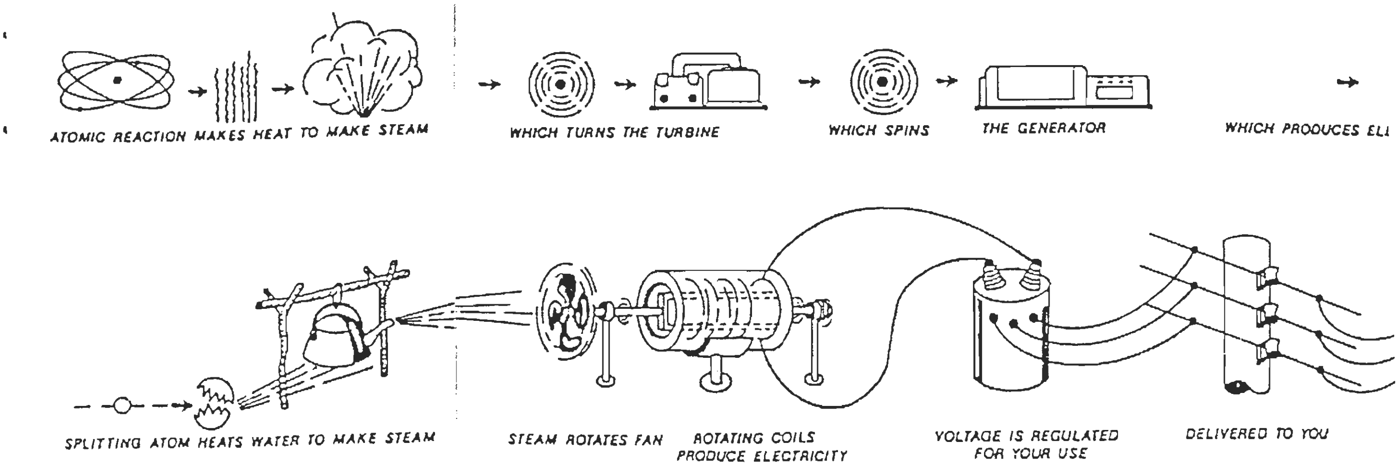
Core -

Coolant -

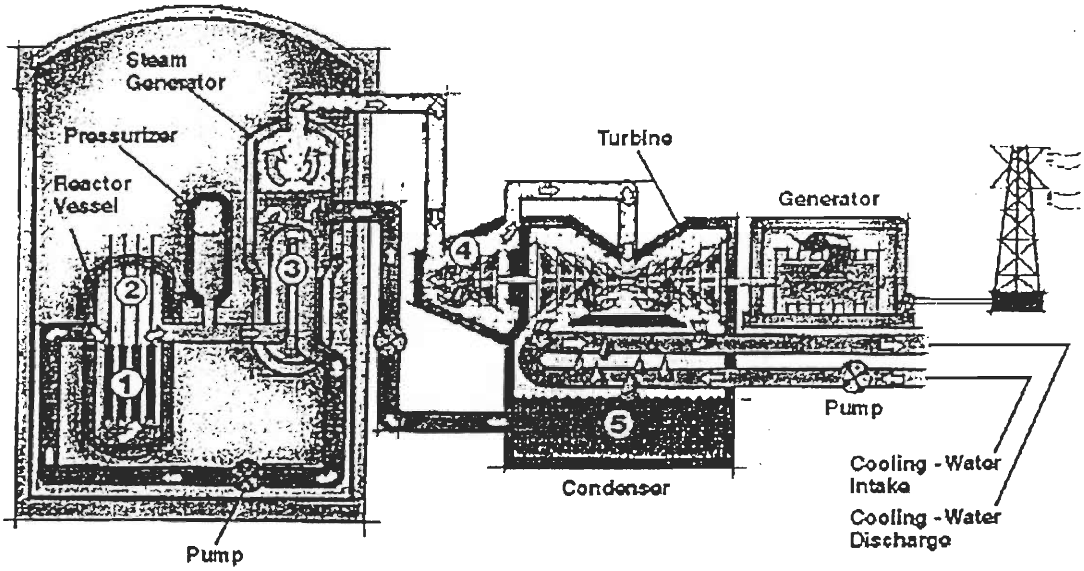
III. The Nuclear Power Plant - an Overview

In a nuclear reactor, heat is removed from the Uranium fuel, by water and used to make steam. Steam spins the __________ which look like fan blades, which turns the electrical generators which are connected to the electrical distribution grid.

Here is a simple illustration of the entire process:



A model of a power plant:



What are the following components in the Power Plant?

Pressurizer:

Steam Generators:

Coolant Pumps:

The primary system is ______________, the secondary side is not.

Grade Eight Nuclear Power Notes - Radiation

Name: TEACHER ______________________________

I. An atom is ______________ when it emits high-energy particles. These particles are in the form of ______________, ______________, ______________ and ______________ .

Their rank in order of penetrating ability from least to most is:
Also list examples of what materials can stop them.

Radiation is measured in ______________. The prefix "milli" means ______________.

Draw the possible scenarios in which radioactive particles affect the human cell:

Define: dose ______________________________

____

Non-occupational doses

Source:	Your radiation dose:
Cosmic Radiation	
Earth's Crust	
Natural radioactive material in your body	
Building materials (ie:bricks)	
Radon gas	
Medical X-rays	
Jet air travel	
Consumer products (ie: watches, TV's, smoke detectors)	
Smoking	

From a Nuclear Power Plant...

Limit for Power plant workers

Limit for members of the public

Average Nuclear Plant worker dose

Annual dose from background radiation

Living for one year near a nuclear power plant

On the back of this sheet, discuss the concepts of time, distance and shielding to protect you from radiation

WORCESTER POLYTECHNIC INSTITUTE

NUCLEAR REACTOR FACILITY

HISTORY

THE WPI REACTOR WAS MADE POSSIBLE BY A GRANT OF $150,000 FROM THE U.S. ATOMIC ENERGY COMMISSION IN JUNE OF 1958. THE REACTOR WAS CONSTRUCTED BY THE GENERAL ELECTRIC COMPANY FOR WORCESTER POLYTECHNIC INSTITUTE AS A 1 KW REACTOR AND FIRST ACHIEVED CRITICALITY IN DECEMBER OF 1959. THE REACTOR WAS UPGRADED TO 10 KW IN 1967 AND THE 20 YEAR OPERATING LICENSE WAS RENEWED IN 1983 BY THE U.S. NUCLEAR REGULATORY COMMISSION.

IN 1989, THE REACTOR FUEL WAS CHANGED FROM 93% ENRICHED URANIUM TO 20% ENRICHED URANIUM AS A RESULT OF A RULE BY THE USNRC REQUIRING ALL NON-POWER REACTORS TO CONVERT TO LOW-ENRICHED URANIUM.

DESCRIPTION

THE WPI REACTOR IS A "SWIMMING POOL" TYPE REACTOR, WITH AN 8 X 8 X 15 FOOT POOL OF DEMINERALIZED WATER CONTAINED IN AN ALUMINUM LINED CONCRETE STRUCTURE WITH 5 FOOT THICK WALLS. THE REACTOR CORE IS AT THE BOTTOM OF THE POOL CONSISTING OF 21 FUEL ELEMENTS ARRANGED IN A 15" BY 24" GRID. EACH FUEL ELEMENT IN THE CORE CONSISTS OF 18 FUEL PLATES, WHICH ARE MADE OF AN ALUMINUM-URANIUM ALLOY CLAD WITH ALUMINUM.

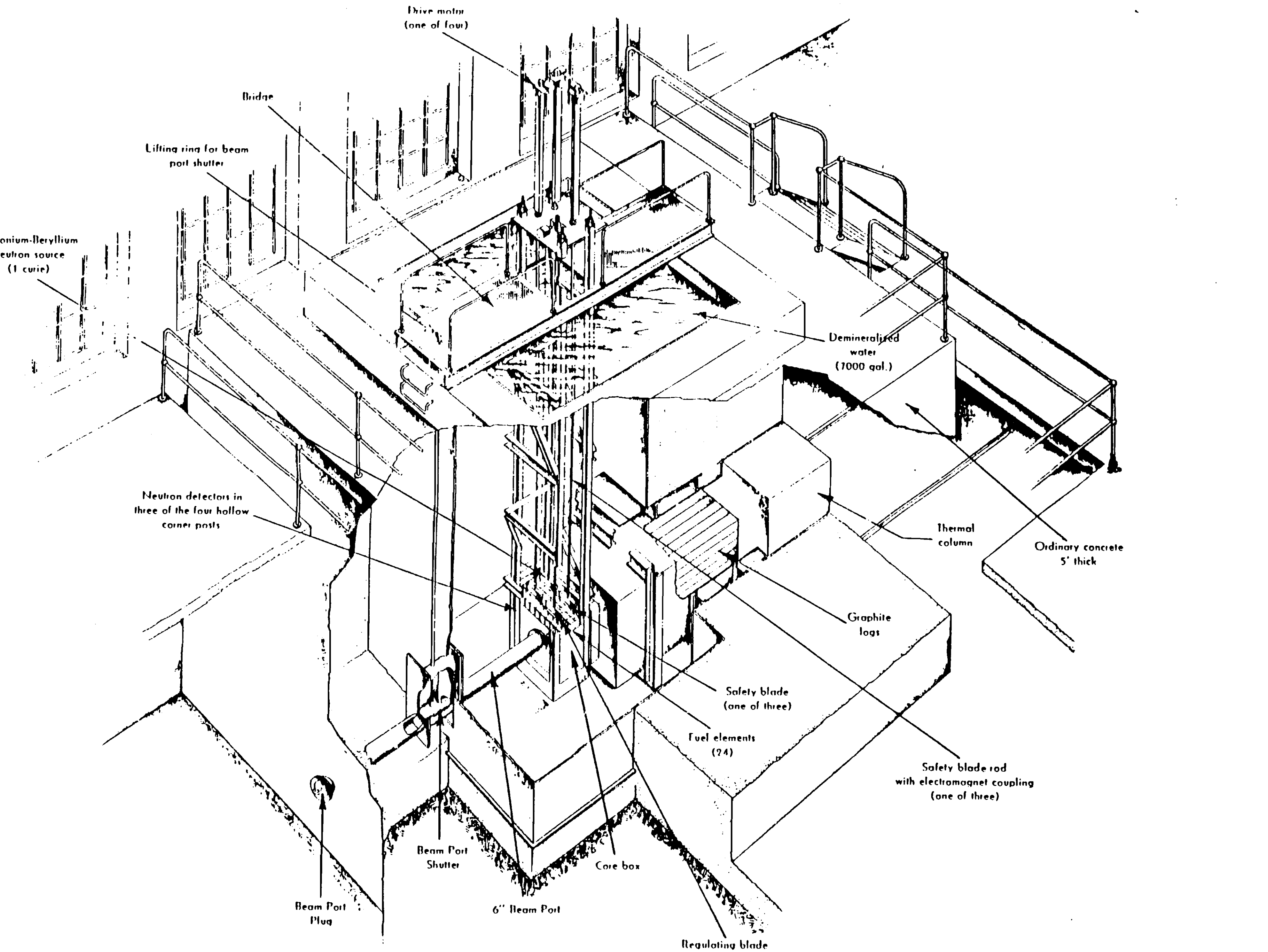
THE 10 KW OF THERMAL ENERGY PRODUCED BY THE REACTOR IS DISSIPATED BY NATURAL CONVECTION OF THE WATER SURROUNDING THE CORE. THE AVERAGE WATER TEMPERATURE AT FULL POWER IS ABOUT 80^{o}F. BECAUSE OF THE LOW POWER LEVEL OF THE REACTOR, FUEL BURNUP HAS BEEN NEGLIGIBLE THROUGHOUT THE YEARS OF OPERATION OF THE REACTOR.

CONTROL OF THE REACTOR IS ACCOMPLISHED BY THREE BORAL SAFETY BLADES AND A STAINLESS STEEL REGULATING BLADE. THE INSERTION OF ANY ONE OF THE BLADES IS SUFFICIENT TO TERMINATE THE OPERATON OF THE REACTOR.

FACILITIES

THE OPEN POOL DESIGN OF THE REACTOR ALLOWS FULL ACCESS TO THE CORE AND PROVIDES A CONVENIENT MEANS OF OBSERVING AND MEASURING CRITICAL POWER REACTOR CORE PHENOMENA, INCLUDING THE BLUE GLOW OF CERENKOV RADIATION.

THE REACTOR HAS SEVERAL EXPERIMENTAL FACILITIES, INCLUDING A 6" BEAM PORT FOR NEUTRON BEAM STUDIES SUCH AS NEUTRON RADIOGRAPHY, AND A GRAPHITE THERMAL COLUMN FOR NEUTRON DIFFUSION STUDIES. EQUIPMENT IS ALSO AVAILABLE FOR SAMPLE NEUTRON IRRADIATION AND RADIOISOTOPE STUDIES.



WORCESTER POOL TRAINING REACTOR

Notes & References

2.1 Immediate Effects

Immediate effects are observable shortly after receiving a large single dose of radiation. Most adult tissues are rather robust in their response to radiation. However, there are several organs or tissues that are relatively sensitive to radiation.

The blood-forming system is particularly sensitive to radiation. An acute dose of 50 rem will temporarily suppress the number of blood cells.

The male reproductive system is highly radiosensitive. A temporary reduction in sperm count will occur at doses above about 10 rem. Prolonged sterility may result from doses over about 200 rem.

The lens of the eye is relatively sensitive to radiation. For chronic exposures, a lifetime dose in excess of 500 rem must be received to increase lens opacity and thus some degree of vision impairment.

The immediate effects of radiation, such as the ones discussed above, appear only after a minimum, or "threshold" dose has been received. Table 1 summarizes the probable acute effects of acute whole-body irradiation.

Notes & References

Table 1

Effects of Acute. Whole Body Irradiation

Acute Exposure (rem)	Probable Effects
10	No detectable effect in normal life spans.
25	Radiation effects only detectable by chromosome analysis.
50	Minor changes to blood cells.
100	Possible radiation sickness, skin reddening, in days or weeks. Little chance of death, even without treatment
250	Acute radiation sickness. Recovery likely with medical treatment, but some risk of death in a few weeks if there is no treatment.
450	Half of those exposed would die within 30 days without medical treatment. Some may die in a few weeks even with treatment
1,000	Death within 30 days without medical treatment. High risk of death in days or weeks with medical treatment.

Source: Mettler FA and Moseley, *Medical Effects of Ionizing Radiation*, Grune and Stratton Inc. 1985

It is very unlikely that any radiation exposure received in an Ontario Power Generation, Nuclear generating station by any person would be large enough to cause any of these immediate effects. The legal dose limits and the actual doses received by workers are well below the threshold dose that is required to produce these effects. The typical annual doses received by radiation workers are summarized in Table 2.

Notes & References

Annual Non-occupational Doses

Source	Your Radiation Dose
Cosmic radiation	27 mrem whole body
Radiation from earth's crust (average)	28 mrem whole body
Natural Radioactive Material in your body	50 mrem whole body
Building Materials (average)	3.5 mrem whole body
Radon gas (average; highly variable)	100 mrem whole body
Medical X-rays	
– chest X-ray	7 mrem whole body
– full spine X-ray	64 mrem whole body
– intestinal X-ray	250 mrem
Jet air travel	1 mrem for each hour of flight
Consumer products such as watches, television, radios and smoke detectors	5 mrem
(If you are a smoker, (1 to 2 packs a day) you can add an additional dose of approximately 1300 mrem/year due to lung exposure from radon decay products in tobacco)	

Referenced from The Health Physics and Radiological Health Handbook (1992); NCRP (1994; UNSCEAR (1993); NCRP (1995); AECB 1995 Report:" Canada - Living with Radiation".

Notes & References

The next table compares the average annual dose received by a nuclear worker with some of these sources.

Annual Dose Comparisons

Annual legal limit for radiation workers*	5000 mrem
Annual legal limit for members of the public*	500 mrem
Average annual dose per exposed worker**	250 mrem
Annual dose from natural background radiation in Canada	250 mrem
Living for a year near a nuclear generating station	<5 mrem

Source: AECB, Risk Associated With Radiation, General Information, July 1995; INFO-0577.

* Atomic Energy Control Regulations.

** Based on Ontario Hydro's Annual Dose Summary 1990-1996.

Chernobyl - The World's Worst Nuclear Accident

Name: ____

Definitions:
Sarcophagus - The large cement structure that entombs the site of reactor #4 in order to keep radioactive dust and debris from continuing to escape into the atmosphere.
Roentgen - A quantity of radiation equal to REM (REM = Roentgen Equivalant Man)

Directions: Answer these questions from the video. The answers are not revealed chronologically (in order).

1. What month and year did the Chenobyl reactor #4 melt down? ______________
2. Over how many countries did the "menacing radioactive cloud" cover? _________
3. What is the highest radiation level in R/hr, that the scientists saw in the damaged reactor building inside of the sarcophagus? ____________________ R/hr
4. How many people died from radiation during the effort to control the explosion? __
5. Of the 3 methods for minimizing radiation dose (time, distance and shielding), which method do you see the "complex expedition" scientists utilizing most?

   ____

6. Explain the dangers that still exist at the entombed Chernobyl reactor #4.

7. Write down at least one question you have from the contents of the videoon the back of this worksheet. Be prepared to ask this question in class on Tuesday.

Grade 8 Science - Mr. Cote

Name:_______________________________________

Nuclear Power Unit Test

I. Matching

_____ Process of splitting of atoms

_____ A cube-shaped block of Uranium in a reactor

_____ An immediate shutdown of the reactor by instantly inserting all of the control rods

_____ Wrote a letter to Pres. Roosevelt warning of the potential of nuclear power in WW2.

_____ Type of energy released by the splitting of atoms

_____ Used to remove heat from the reactor core

_____ Cylindrical container that houses the core

_____ Biological shield that contains the reactor and all radioactive materials

_____ Codename of U.S. 's effort to build an atomic bomb

_____ Austrian physisist discovered fission in 1939

_____ French scientist worked with radioactive elements

_____ Electric light bulb in 1879

a. Pressure vessel

b. H.G. Wells

c. core

d. Thermal Energy

e. Albert Einstein

f. SCRAM

g. coolant

h. Manhatten project

i. Pressurizer

j. Fission

k. Reactor Vault

L. Marie Curie

m. Otto Hahn

n. George Orwell

o. Thomas Edison

II. Fill in the Blanks

1. Uranium has an atomic number of **92.** How many protons are contained within its nucleus?

____

2. There are 3 phases of matter. What are they? ______________________________
   Explain how the periodic table is subdivided into these types of matter:

   ____

   ____

3. If you walked into a room that had a known radiation level of 150 mR/hr, and you stayed there for 30 minutes, what would your dose be?

   ____

4. The 4 types of radiation are:

   ______________________ ______________________

   ______________________ ______________________

5. What type of energy is released from fission? ________________________

6. What element is used to control the number of neutrons in fission? ___________

7. The electron cloud has electrons orbiting around at the ____________________

8. Within a nucleus, there are _______________ and _______________. A force that keeps the nucleus together is called the ______________________.

9. List 3 sources that contribute to radiation in everyday life:

   1.____________ 2. ____________ 3.____________

10. What is the MINIMUM lethal dose? (Least amount of radiation that can kill you?)

    ____

III. Short answers

1. Explain the 3 techniques you can use to minimize your radiation dose.

2. Draw the fission model and explain each step. By controlling the number of neutrons, effectively what are you controlling? Explain why we do this!

3. Explain why there is a nuclear force in regards to the charges contained in the nucleus of an atom, and how they interact with each other.

4. Describe what happens in the following three scenerios in which the human cell is subjected to radiation.
   1.

   2.

   3.

Footnotes

1. Shawn Reed, *Nuclear Opinion at WPI and Various New England Colleges: A Time-Line Study* (WPI IQP, 1997), p.8
2. Ibid., p.12
3. Ibid., p.31
4. Robert E. Yager, *The Advantages of STS Approaches in Science Instruction in Grades Four Through Nine* (Bulletin of Science, Technology and Society, 1993) Vol. 13, p. 74-82
5. WPI 1999-2000 Undergraduate Catalog p.3
6. WPI 1999-2000 Undergraduate Catalog p.37
7. Brian Cote, Appendix II - Post Unit Interview, p.54
8. *State of the World 2000 - Challenges of the New Century* p.17
9. Campbell (1950)
10. Charles Martin, CAPT - *Fundamentals Report for the Myers-Briggs Type Indicator* (Gainesville: Florida, 1997), p.3
11. Ibid., p.3
12. Brian Cote, Appendix II - Post Unit Interview, p.55
13. Ibid.
14. Ibid., p.56

Bibliography

Brown, T./ Ginter, D./ Petrovic, C. Radiation Protection Qualification Training. Ontario Power Generation, 1999

Harting, Philip and Wilkie, David. Revision of Nuclear STS Curriculum. WPI IQP #46-JMW-NUC2, 1997

Hirsh, Sandra Krebs. Introduction to Type in Organizations. Palo Alto: Consulting Psychologists Press, Inc., 1990.

National Science Board. Science and Engineering Indicators. Washington D.C.: U.S. Government Printing Office, 1993.

Ontario Power Generation. Introduction to CANDU Processes. Toronto: 1999

Poole, Robert. Beyond Engineering. New York: 1997

Reed, Shawn. Nuclear Opinion at WPI and Various New England Colleges: A Time-Line Study. WPI IQP #1-46-JMW-IONS, 1997

Salvati, Maria. Evaluation of the WPI Sixth Grade STS Initiative. WPI IQP, 1996.

Schlosser, Dana and Volock, Kenneth. Nuclear Power Live Role Playing Game. WPI IQP # JMW-NUC, 1996

Wilkes, John M. Public Knowledge and Interpretation of Nuclear Power Before and After TMI. Annual Meeting of the Society for the Social Study of Science, RPI, Troy, New York. October 25-27, 1985.

WPI 1999-2000 Undergraduate Catalog

Yager, Robert E. The Advantages of STS Approaches in Science Instruction in Grades Four Through Nine (Bulletin of Science, Technology and Society, 1993) Vol. 13