> Knowledge has killed the sun, making it a ball of gas with spots… The world of reason and science… this is the dry and sterile world the abstracted mind inhabits.[1] *D.H. Lawrence*

> A public that does not understand how science works can, all too easily, fall prey to those ignoramuses… who make fun of what they do not understand, or to the sloganeers who proclaim scientists to be the mercenary warriors of today, and the tools of the military. The difference… between… understanding and not understanding… is also the difference between respect and admiration on the one side, and hate and fear on the other.[1] *Isaac Asimov*

> Scientists aren't saints. Although few falsify results, the field is so competitive that many misbehave in other ways.[2] *David Goodstein*

Chemical Conversations about Ethics and the I.S.O.C. Reaction

An invited talk for the 2003-2004 "Digging Deep Within A Discipline - Cultivating a Moral Imagination Series" hosted by the Chair of Moral Values, Augustana College by Jetty L. Duffy-Matzner, Ph.D.

Abstract

The scientific method - fact or fiction? Is science simply an uncovering of natural facts and thus placed above the moral questions of right and wrong? Is sloppy science really sloppy and/or fraudulent?

These questions and others will be addressed in this conversation about moral judgments and it's intricate relationship with the development of technologies and science. Many people tend to think of scientific facts and not consider the haphazard and convoluted pathways that were undertaken to discover our "textbook science"[3]. Much of science has resulted from accidental discoveries and a bias (sometimes undeserved) towards the scientist's trained intuition. This presentation will also examine the questionable idea that scientists have a code of ethics and how this can affect the interactions between scientists and others, such as granting institutions. This conversation will also explore the relationship between research students and faculty as mentors in professional development and scientific integrity. Finally it will conclude with the examinations of a current research project and the necessary and often unexpected moral dilemmas that are encountered in the pursuit of science.

Introduction

What "age" do we live in? Is there an aspect of societal life that can be used to define the last century? I believe that there is an enthusiastic, affirmative answer to these questions. This year marks the 100th anniversary for man and flight. The human genome project has been completed. Infant birth deaths and death rates in the elderly are at an all time low. We have modified bacteria to produce insulin for us and modified feed so that it will control deer population growth. We live in air-conditioned and centrally heated offices and homes. We drive cars that are the ultimate in luxury and occasionally in efficiency. Most importantly, we have strawberries and fresh flowers year round in Sioux Falls, South Dakota! Science has changed the world forever. Technology, using science to solve practical problems, is such a part of our lives that few of us even notice our total dependence on it. In this end even the layperson should have a moderate understandings of the working of scientists. This seems to be a classic case of the quote "easier said than done." There seems to be a natural (or unnatural) division between science and the public. On the other hand there seems to be a division between scientists and conveying the methods by which they work to the public. These views are voiced in the following quote, "science is underfunded, underappreciated, and under the scrutiny of a public that is unschooled in its fundamentals… This generates an atmosphere of fear, bewilderment, disdain… and…mistrust," as stated by Nobel Laureate, J. Michael Bishop.[4] This is so amply demonstrated by the public fear of white-coated, mad scientists that exist in literature such as Mary Shelley's Frankenstein.

What then is science and why is there this chasm? When confronted with this question I turned to the book of all knowledge (the dictionary) and looked up the laypersons terms for science and scientific method.

> Science - the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena (observable events). 5. any activity that appears to require study and method. 6. knowledge gained through experience.
>
> Scientific Method - The totality of principles and processes regarded as characteristic of or necessary for scientific investigations, generally taken to include rules for concept formation, conduct of observations and experiments, and validation of hypotheses by observations and experiments.[5]

It is interesting to note the definition offered for science is knowledge gained through experience, but I doubt any scientist would agree that it is limited to our field and actually may not apply at all to science (more on that later). I then turned to a basic science textbook that I use for my physical science course to examine these definitions.

> What is a scientific investigation and what methods are used to conduct one? Attempts have been made to describe scientific methods, sometimes in a series of steps, but no single description have ever been satisfying for all concerned. Scientist do similar things in investigations, but there are different approaches and different ways to evaluate what is found. One thing is certain, however: scientists do not follow a routine of certain steps in an investigation. The approach depends on the individuals doing the investigation as well as the particular field of science being studied. One way to understand the nature of this divergent approach to scientific investigations is to consider what all the separate fields have in common: the gathering of facts and data to provide explanations and the development of scientific laws and theories.[6] *Bill W. Tillery*

Instead of the logical procedure listed in the dictionary, Tillery is very careful to point out that the scientific method is very dependent on the individual and is NOT dependent on a prescribed formula or series of steps. This is one misconception that I saw published in many of the treatises concerning science and the ethics of science that were authored by nonscientists. Even people who had obviously done a bit of research on the topic missed this very important aspect. Two well respected journalists, Broad and Wade's, wrote the book, Betrayer's of the Truth, which actually begins with the statement, "This is a book about the way that science really works"[7] and then continues with a recipe for the scientific method. The nature of the inquiries into the natural world that we label as science does not follow a recipe. This fundamental difference can block the understanding of how science actually works and helps explain why the public can be confused by scientific methods.

The *Star Trek* saga uses the Vulcan race as the premiere scientists of the future. It may be illuminating to look at some of the defining features of this fictional species that may play a role in the public perception of science. Vulcans are driven by a large sense of curiosity, they act out their lives based solely on logic, they are willing to act as mentors to technologically poorer races (such as us humans), they have found it necessary to control their emotions to the extent that they don't appear to have any, and they arrogantly believe that their superior knowledge gives them the right to control the destiny of other races because of their advanced physiology. I wonder how many people believe that these qualities define the scientific community? David Goodstein, vice provost and professor of physic and applied physics at the California Institute of Technology, comments on this misconception by the label, the Noble Scientist.

> The self image of most scientists, and I think the image held by much of the public as well, amounts to what I call the Myth of the Noble Scientist. The Noble Scientist is supposed to be more virtuous and upright than ordinary mortals, impervious to the baser human drives, such as personal ambitions, and, of course, incapable of misbehaving in even the smallest way. The myth originates, I would guess, in the Baconian view of the scientist as a disinterested observer of nature. Although Francis Bacon's version of the scientific method has long since been discredited by philosophers and historians of science, it lingers in the public mind, and even some scientists continue to pay lip service to it. Reality, however, differs substantially from the Myth of the Noble Scientist.[8]

The "Real" Scientist

How then does real science happen? What is the source of the division between science and the public? Is it just the use of advanced knowledge and if so, is this the same as the differences between any profession and the public: lawyers, plumbers, accountants etc. I don't think so. Lewis Wolpert, an English research biologist in the field of embryology, has the following to say in his book titled the Unnatural Nature of Science, "(The) world is not constructed on a common-sensical basis. This means that natural thinking - ordinary, day to day common sense - will never give an understanding about the nature of science.[10] Let us turn to a look at common perceptions that may inhibit people's understanding of the sciences, two of these are causality and scale.

Causality can be defined as the relationship between cause and effect. This is a concept is something that is basic to our day-to-day routines. Toddlers explore this effect, to the frustration of their parents, on a moment-to-moment basis. I would like to propose that this relationship coupled with our common sense stymied the growth of science. Let us turn our attention to the laws of motion. One of the first theories proposed by Philoponus in the 6th century and revisited by John Buridan in the 14th century was the Impetus theory.[11] This theory assumes that the act of setting something in motion provides that object with a force or impetus to keep it moving. This seems perfectly realistic based on our common sense. A marble rolling along the floor must have a force acting on it in the direction that it is traveling. It makes sense, unfortunately it is wrong. Newton's experiments showed that a marble rolling along at constant speed and without a change in direction has no net forces acting on it. A force was required to overcome inertia, but once the inertia overcome, no force is required. Indeed Newton's first law of motion is that simply, an object at rest will stay at rest and an object in motion will stay in motion. Once again this is contrary to our common sense. A marble rolling along the floor will not keep moving, it will slow down and eventually stop. However this is because of the unbalanced force due to friction, it is not a natural part of motion of the marble. Science, unfortunately, is not simple. The cause and effect of motion are not the same as our common sense would lead us to believe. Let me ask the reader a question (since this is a conversation after all). You are standing on a very large and flat field with a pistol. How long will it take a bullet fired from the pistol to reach the ground versus one that you drop from the opposite hand at the same time that the pistol is fired? The answer is that they will both hit the ground at the same time. They both fall at exactly the same rate due to gravity. The only force that is acting on both of these after the gunpowder explosion is gravity. There is no horizontal force acting on the bullet after that. The common sense approach of Impetus is incorrect. Scientists have to be trained to think along pathways that gaze into the understanding of how nature works, but not as a layperson would use their common sense, because common sense will fail.

Another idea that seems to inhibit the understanding of science is scale. The sheer enormity or teeniest of the numbers that scientists work with can be truly amazing and often incomprehensible to lay person with seemingly no basis in our daily experiences. I will attempt to demonstrate the size of molecules, the building blocks of matter. Take a glass of water and throw it into the ocean. Wait many years and then refill the empty glass with, the now mixed up, ocean water. Do you expect that glass to now contain any of the original H_2O molecules? The answer would be, of course! One could then conclude that there are many more (like way more) water molecules in a glass of water, than there are glasses of water in the ocean.[11]

Let us return to the question, how science is done. The answer is very carefully in many different forms. The following is a quote from Lewis Wolpert on how to make a discovery in science.

> … many famous scientists have given advice: try many things; do what makes your heart leap; think big; dare to explore where there is no light; challenge expectation; cherchez le paradox, be sloppy so that something unexpected happens, but not so sloppy that you can't tell what happened; turn it on its head; never try to solve an answer until you can guess the answer; precision encourages the imagination; seek simplicity; seek beauty…. One would do no better than to try them all. No one method, no paradigm, will capture the process of science. There is no such thing as ***the*** scientific method.[12] *Lewis Wolpert*

One of the neat things about being a scientist is that you don't have to know all the answers. This has been true throughout the history of science. Newton discovered the natural law of gravity. This is an attractive force that exists between two bodies. The force is proportional to the masses of the objects and indirectly proportional to the distance that separates them. The great German mathematician, Lebnitz was a critic of Newton's new ideas. Sir Issac Newton explains his position on the topic in his rebuttal.

> It pleases some to return to occult qualities… but because these have become unrespectable they call them forces, changing the name. …it can never be cleared up, even though some spirit, not to say God himself, were endeavoring to explain it. *Baron Gottfried Wilhelm von Lebnitz*
>
> I have not been able to deduce from phenomena the reason for these properties and I do not feign hypotheses.[13] *Sir Issac Newton*

I have often tried to explain this notion to my freshman students with the following story. You are working alone in lab wondering if you have the drawn the correct conclusions or not. Then suddenly a brilliant light appears and a booming voice announces, "Well done, faithful laboratory servant, you have obtained the right answer, with the perfect analysis of the problem; go home and celebrate!" NOT! If this happens, go see the nice mental health people. Science is about uncertainties. This can also be seen in our modern leaders in the sciences. The following is a quote from Murray Gell-Mann, one of the founders of modern physics, in answer partly to

Einstein's famous quote, "God doesn't play dice". Even Einstein had a hard time with the absence of causality (as we know it) in the subatomic world,

> All of modern physics is governed by that magnificent and thoroughly confusing discipline called quantum mechanics invented more than fifty years ago. It has survived all tests. We suppose that it is correct. Nobody understands it but we all know how to use it and how to apply it to problems. And so we have learned to live with the fact that nobody can understand it.[14] *Murray Gell-Mann*

<u>Scientific Code and Ethical Conduct</u>

So then if scientists true role is just to discover how nature works and if this can be quantified into discrete numbers most of the time, can there be a moral or ethical role in the scientific method? After all, facts are facts! Unfortunately, yes, the end result is very dependent of the manner used to obtain it. Scientists are humans and humans make mistakes. This is stated below as part the National Academy Press web site for training materials for scientific ethics courses.

> Scientific results are inherently provisional. Scientists can never prove conclusively that they have described some aspect of the natural or physical world with complete accuracy. In that sense all scientific results must be treated as susceptible to error. Errors arising from human fallibility also occur in science. Scientists do not have limitless working time or access to unlimited resources. Even the most responsible scientist can make an honest mistake.[15]

Thus it is accepted that conclusions drawn from a study may (and probably do) have some flaws and that different people may have come up with a different interpretation of the data. This is built into how science works. Peer review plays a very large role in both obtaining funding for an idea and publishing the findings. Convincing others that one's theories and conclusions are correct is part of playing the scientific methodology game. If the argument is weak, the research activities will not be continue to be supported. So is there a code of ethics at the heart of this game? I certainly hope so, although it is understood that there will be differences of opinion and small distortions are allowed, but major deviance from scientific practice is not to be condoned. David Goodstien writes about some of the allowed fudging.

> No human activity can stand up to the glare of relentless, absolute honesty. We all build little hypocrisies into what we do to make life a little bit easier to live. Because science is a very human activity, hypocrisies and misrepresentations are built into the way we do it. For example, every scientific paper is written as if that particular investigation were a triumphant procession from one truth of another. All scientists who perform research, however, know that every scientific experiment is chaotic - like war. You never know what is going on; you cannot usually understand what the data mean. But, in the end, you figure out what it was all about and then, with hindsight, you write it up describing it as one clear and certain step after the other. This is a kind of hypocrisy, but it is one deeply

> embedded in the way we do science. We are so accustomed to it that we don't even regard it as a misrepresentation anymore.
>
> Glossaries explaining the real meanings of terms found in scientific papers occasionally make the rounds of laboratories. For example, "owing to difficulties in sample handling" really means something like " we dropped it on the floor." "It has long been known that" means "I haven't bothered to look up the original reference." "Typical results are shown" means "these are the best set of data I ever managed to get."[16]

Another interesting idea is that the very nature of scientific methods may interest the philosophers and sociologists but bear only marginal interest or relevance to the practitioners of the field. Scientists are focused (some might say obsessed) with discovering how nature works in their small niche of the field. They expect to disagree with someone's findings, but not to question whether that data was actually collected or misrepresented. They expect that not all the convoluted paths that were explored may be included as part of the publication, but that the important data will be correct and honestly represented. As stated by Frederick Grinell, " Other researchers will expect to be able to verify the data and the conclusions, not the adventures and the misadventures that led to them."[17]

Since scientists tend to be rather self-naïve when it comes to ethical conduct; why has there been so much attention paid to the area of scientific ethics, both outside and inside the profession in the past two decades? The answer lies somewhat surprisingly with the defeated candidate of the last presidential election. In 1981 Albert Gore was the chair of a subcommittee of the House Committee on Science and Technology which was investigating scientific fraud. The president of the National Academy of Sciences, Philip Handler "made a presentation to the committee in which he told them, more or less, that this was something beyond their understanding and that they should keep their grubby hands out of it. Handler's view was not exactly well received by Congress, whose members felt that the scientists, after all, were being supported by the public, and ought to accept congressional oversight."[18] Thus the governmental agencies that provide scientific funding had to come up with policies. They also insisted that institutions that receive such monies, have policies and procedures in place to deal with scientific misconduct. The following are statements as to what defines scientific misconduct for both the National Institutes of Health and the National Science Foundation. The NIH is an agency of the U.S. Public Health Service, USPHS. One of the provisions of the NSF definition was "serious deviations within the scientific community" and caused several contentious arguments within the scientific community concerning the exact definition for this ambiguous term. Many scientists were fretful that it would limit novel and unorthodox research, hence the last statement is a clarification of this language by Donald E. Buzzelli, Senior Scientist in the Office of Inspector General.

> Misconduct or "Misconduct in Science" means fabrication, falsification, plagiarism, or other practices that seriously deviate from those that are commonly accepted within the scientific community for proposing, conducting or reporting research. It does not include honest error or honest differences in interpretations or judgments of data.[19] *USPHS*

> Misconduct means fabrication, falsification, plagiarism or other serious deviations from accepted practices in preparation, carrying out, or reporting results funded by NSF, or retaliation of any kind against a person who reported or provided information about suspected or alleged misconduct and who has not acted in bad faith.[20] *NSF*

> How to interpret NSF's Definition
> This definition says in effect, that misconduct in science is serious deviation from standard practices. Falsification, fabrication, and plagiarism are mentioned as outstanding examples. Then the definition goes on to say that all other actions that similarly deviated from accepted practices are also misconduct in science… The way to commit misconduct in science is to do something that scientists would recognize as deviating seriously from the professional ethical standards.[21] *Donald E. Buzzelli, Senior Scientist in the Office of Inspector General, NSF*

While most scientists believe strongly that cases of scientific misconduct are rare, policies should be in place to protect science and to inhibit the temptation to cross the border into unethical conduct. There is some dread that focusing on the bureaucracy versus the implementation of science may stunt the growth of further creative research as is demonstrated by Goodstein.

> Nevertheless, fraud does sometimes occur in science, and universities were certainly poor equipped to deal with it before the PHS and NSF forced us to put our houses in order and write down and adopt regulations. It is easy to predict that we will be seeing more cases of scientific misconduct for a while; the very existence of rules and regulations and bodies designed to cope with the problems tends to make cases emerge. I can only hope that we won't wind up arranging things in such a way as would have inhibited Newton or Millikan from doing their thing.[22] *David Goodstein*

I believe that the following quote typifies the response of most scientists to the call to prepare for ethical considerations but also to keep a sense of focus on the science. Howard K. Schachman is a professor in the Department of Molecular and Cell Biology a the University of California, Berkley. He reminds us to remember that scientists are, after all, only human.

> Many scientists, like others in our society, are ambitious, self-serving, opportunistic, selfish, competitive, contentious, aggressive, and arrogant; but that does not mean that they are crooks. It is essential to distinguish between research fraud on the one hand and irritating and careless behavioral patterns of scientists, no matter how objectionable, on the other. We must distinguish between the crooks and the jerks.[23] *Howard K. Schachman*

It is also important that scientists play a large role in the definitions, regulations and penalties associated with scientific fraud. As Donald Buzzelli states, "But those who wish to make useful policy recommendations also need the insights of those with day-to-day experience in this highly controversial area."[24] Scientists are best suited to safeguard and understand the limits of ethical misconduct in the field, as long as they are forced to by the funding agencies that control the funds needed to pursue their work. This balance is a good one. Scientists may know scientific fraud from sloppy science or even cutting-edge science, while others may not. The last quote in this section from David Goodstein explains this justification.

> And to make matters worse, one might argue that, if all scientists rigorously adhered to proper scientific procedure at all times, very little scientific progress would occur. To understand this argument, let us turn to a journalistic account of the issue of scientific fraud, <u>Betrayers of the Truth</u>. The book has an appendix entitled "Known or Suspected Cases of Scientific Fraud."… In addition to Hipparchus and Ptolemy, (the authors) Broad and Wade (also) list…Galileo, Newton, Dalton, Mendel and Millikan. If one subtracts (these) from the body of science… and, of course, all that follows from their work - there would not be much left. Yet the journalists never consider the deeper implications of concluding that so much of our scientific knowledge is based on fraudulent work. Broad and Wade may have stood on the shoulders of giants, but they have not seen very far.[25]

<u>Mentors in Science and Their Ethical Responsibilities</u>

Since I teach at a small, private undergraduate institution I am sure that I can now hear the collective sigh of the audience at finally arriving at the "good stuff". I doubt that it would surprise anyone, that a scientist (or any faculty member regardless of field) should feel the call to mentor young people as students in their classes. It might surprise some to learn that I feel it is also the duty of the scientist to mentor these people as young scientists, a classroom is not indicative of the profession. I believe that it is the duty of a scientist to involve themselves (and students) in some manner in the field (or laboratory or clinic). It keeps the professor active and challenged in their fields. It also provides the students with a very important opportunity to train with someone who has the motivation and desire to ensure a positive and rewarding experience for the trainee. Kristin Shrader-Frechette has the following to say on the subject.

> Professors are expected to contribute to the knowledge in their field, and to work with students to do so… Publications lead to evaluation of professional work. Researcher submitting their work for publication is thus comparable to pilots undergoing periodic testing. Both procedures enable professionals to keep their skills at a level necessary to fulfill their duties.[26]

Shrader-Frechette also goes on to mention some of the principles guiding the ethical conduct that should be instilled in the developing scientists. Among these are careful safeguarding against one's own bias and the unbiased use of research in general. One should leave the students with the passion to improve the quality of life for the present and future inhabitants of the earth. One should discuss one's findings to the public, other professionals and employers. One ought to engage in whistle-blowing when appropriate.[27] Many of our students will go on toward professional schools: medical, pharmaceutical, dental and graduate studies in the sciences. They need to have these values carefully implanted in their young and fertile minds before the stress and rigor of these programs. We have to remember that as Francis L. Macrina so eloquently states, "trainees emerge from their programs with an intellectual and ethical framework strongly shaped by their mentors. Indeed trainees often assume the traits and values of their mentors. Thus mentors are the stewards of scientific integrity."[28]

Clarice Yentsch and C.J. Sniderman published a list of mentor activities after interviewing many students.

1. Demonstrating a style and methodology of doing research
2. Developing an analytical approach to selection of significant questions and choosing appropriate approaches to solving them.
3. Discussing the concepts in any sub discipline, and the evolution of those concepts over time
4. Exploring and evaluating the literature of the discipline and the broader body of knowledge of which it is a part
5. Discussing the ethical basis for scientific research
6. Considering, analyzing and evaluating the work and conclusions of colleagues
7. Transmuting, by example and discussion, the skills required for effective scientific writing
8. Facilitating access to the research community
9. Illustrating the methodology and significance of networking[29]

Notice that even young professionals recognize the need for the frank discussion of scientific ethics with a mentor. Even faculty at larger institutions recognize the important role that the mentor plays in advancing a student's awareness of professional ethics. Students need to be more than just laboratory rats (cheap source of labor) or a means to achieving a publication record.

> We tend to forget that students, the seed corn of our profession, are quite idealistic. If they start to feel collectively that the research enterprise is just a publication game, it will get very much harder to turn the best and brightest young minds on to science. There is already a fair amount of cynicism out there.[30] *Christopher A. Reed*

> Courses are not offered in the rules of misrepresentation in scientific papers, but the apprenticeship that one goes through to become scientists does involve learning them. That same apprenticeship, however, also inculcates a deep respect for the inviolability of scientific data. It teaches how one distinguishes the indelible line that separates harmless fudging from real fraud.[31] *David Goodstein*

It is easy to "grade" a student's achievements (or lack thereof) in a classroom setting. This may not be so easy to do in a research setting. Francis L. Macrina has the following advice:

> Gauge a trainee's performance by three principal means
> 1. Direct laboratory observance
> 2. Viewing trainee's raw and analyzed research data
> 3. Listening to presentations at both formal and informal settings.[32]

I have had a chance to work with research students on a project that I proposed for NSF for the past three summers. It was nice to see the protocols that were followed during this time were indeed validated by Macrina's comments. I have my students turn in copies of their experimental data along with their typed weekly report. As a chemist I need to not only observe my student's but train them in the proper procedures (and to keep Gilbert Science Center smoke free and standing). The chemistry department has weekly meeting, in which the students have the opportunity to stand in front of the faculty and other students and report their weekly results. They also give a presentation over their research for the department and other students during the academic year. My students have attended regional and national meetings of the American Chemical Society. I believe strongly that they have found these experiences to be challenging yet rewarding and have enjoyed themselves almost as much as I have enjoyed working with them.

The I.S.O.C. Reaction

The time that I have spent working with students at Augustana College has been a treasure trove of joy and frustration and more joy. My research centers on a 1,3-dipolar cycloaddition reaction called the Intramolecular Silyl Nitronate Olefin Cycloaddition (ISOC). In short we make small rings and these compounds have the possibility of serving as precursors for novel macrocyclic antibiotics. This roughly translates as a large molecule that could have interesting biological properties with the chance of actually doing something useful.

As a synthetic heterocyclic chemist, I am interested in the methodology of the cycloaddition step. There are many intriguing potentials that can be explored. NSF doesn't hand out money to scientists just so they can satisfy their professional curiosity. Thus one must come up with a way to sell the research to the funding agency, in this case as a plausible source for a new antibiotic. Borderline ethical marketing practices perhaps, but a necessity in obtaining grant funding. The review panel luckily saw the need to explore the cycloaddition step and so my group was able to focus on that chemistry with a side-burner project funded through the BRIN NIH grant to examine the production of the macrocycle. Thus one project was able to achieve funding sources from two federal agencies, this normally is not allowed. But since the NSF project became centralized on the making of the small molecules the NIH project could investigate the production of the larger molecules.

Other interesting ethical questions that are asked of a leader for a research group is how many students to employ versus how much to spend on supplies versus how much to pay yourself and your collaborators. Granting agencies often list an maximum amount of money that can be spent on the grant - they don't indicate how to spend it in order to get the job done. I wanted to employ as many students as I could, that decision controlled the distribution of the funds for the project. I collaborated with Dr. Arlen Viste on many aspects of the computational parts of this project. Professor Viste was paid zero dollars for all of his work. (Professor Viste is a wonderful man and I really owe him.) I also limited the amount of money that would be paid as a salary for the project leader. Once again, an unexpected moral dilemma arose and had to be confronted. The changes in staffing in the chemistry department converted my position to part-time. I had to seek other employment opportunities to help pay for the daycare of three children during these 10 weeks of summer. Fortunately, I was able to teach a summer course at Augustana. Unfortunately, this decision limited my availability to both my research students and my classes. I felt like I cheated both of these groups. I think this is a perfect example of showing that sometimes even with the best intentions, situations arise that challenge our moral and/or ethical stances. How we respond to these situations and how we influence our students through some of these difficult times, makes us stronger and provides our students with an example of how to interact in a non-perfect world and make it work.

Conclusions

In May of 1953 the United States tested two atomic bombs in Nevada. The radioactive materials covered a large area and ten herds of sheep were exposed. 4,500 sheep died and many of the ranchers lost their livelihoods. Researchers for the U.S. Atomic Energy Commission were coerced by their superiors to state that the weapons test were not responsible for the death of these animals. Many of the ranchers went bankrupt. Between 1951 and 1963, there were more than 100 above ground tests in this state. A 1991 medical study concluded that an additional 2.4 million cancer deaths world-wide will have been caused by these tests. In 1990 the U.S. Congress decided to compensate people or family members who could prove harm from the fall out.[33] Scientific misconduct includes the responsibility to whistle-blow against wrong doers. Science failed the public in this atrocious act of cowardice. Science (and applied science, technology) has a great potential to help mankind. Scientific misconduct has an immense potential to hurt the public. The public funds scientific research either through governmental agencies and/or buying products from industry itself. Thus a scientist has an immense responsibility to protect the practice of science and the public.

However just as scientific misconduct was not responsible for the creation of Mary Shelley's Frankenstein, it was also not responsible for the utilization of an atomic bomb against Japan just as it is not responsible for the use of nerve gases in the time of war. That responsibility lies on society at large with a democratic government, please examine the words of Robert Oppenheimer and Thomas Jefferson.

> The scientist is not responsible for the laws of nature, but it is the scientist's job to find out how these laws operate. It is the scientist's job to find the ways in which these laws will serve the human will. However it is not the scientist's responsibility to determine whether a hydrogen bomb should be used. That responsibility rests with the American people and their chosen representatives.[34]
> *Robert Oppenheimer*

> I know of no safe depository of the ultimate powers of society but the people themselves, and if we think them not enlightened enough to exercise that control with wholesome discretion, the remedy is not to take it away from them, but to inform their discretion.[35] *Thomas Jefferson*

It is important to remember that science is not bad or good. The potential remains for both of these in the applications that are chosen. Science is concerned with the collection of knowledge of the universe around us. Scientists and lay people alike need to be educated as to what defines scientific misconduct. As a scientist myself, I feel a strong call to try and bridge the chasm that exists between the profession and the public. It is important to learn about science and scientific methods. They impact everyone in so many different ways, esp. in our advanced technological world. It is important to realize that textbook science (science which has been subject to the test of time) it unlikely to change and is probably understood very well by the scientific community.

However, “frontier science” is what we are currently exploring and probably don't have all the answers yet.[34] Thus eggs in your diet may be good for you one year and bad for you the next. This would be the shifting nature of “frontier science”, the theories change as more information is gathered. We as a society need to be aware of the true nature of scientific research so that we can know which claims to trust and what information may be a form of scientific fraud. “Proven effective via scientific testing” gives very little information, as a society we can no longer afford to be scientifically naive. I would like to conclude this paper with two quotes from David Goodstein concerning scientific misconduct and our future.

> Unfortunately, instances of scientific misconduct may not remain as rare as they have been in the past. Throughout most of its history, science was constrained only by the limits of its participants ' imagination and creativity. In the past few decades, however, that state of affairs has changed dramatically. Science is now held back mainly by the number of research posts and the amount of research funds available. What had been a purely intellectual competition has become an intense struggle for scarce resources. In the long run, this change, which is permanent and irreversible, will probably have an undesirable effect on ethical behavior among scientists. Instances of scientific fraud will almost surely become more common, as will other forms of scientific misbehavior.
>
> Most scientists are rigorously honest about what really matters to them, like the accurate reporting of procedures and data. In other areas, however, such as disputes over priority or credit, they tend to behave as the ordinary mortals they are. Scientists are not disinterested truth seekers; they are more like players in an intense, winner-take-all competition for scientific prestige and the resources that follow from that prestige. The sooner we admit to those facts and learn to distinguish between serious scientific misconduct and common human conduct by scientists, the better off we'll be.[36] *David Goodstein*

References

1. Wolpert, L. 1993. *The Unnatural Nature of Science*, p ix. Harvard University Press, Cambridge, MA.
2. David Goodstein (Academe, http://www .aaup.org/publications/Academe/02JF/02jfgoo.htm).
3. Bauer, H. 1992. *Scientific Literacy and the Myth of the Scientific Method.* University of Illinois Press, Chicago, IL.
4. Macrina, F.L. 1995. *Scientific Integrity, An Introductory Text with Cases*. p. 7. American Society for Microbiology, Washington, D.C.
5. Morris, W. (ed) 1981. *The American Heritage Dictionary of the English Language*. Houghton Mifflin Company, Boston, MA.
6. Tillery, B.W. 1999, *Physical Science*, p. 16. WCB McGraw Hill, Boston, MA.
7. Broad, W., and N. Wade. 1982. *Betrayers of the Truth; Fraud and Deceit in the Halls of Science*, p. 7. Simon and Schuster, New York.
8. Goodstein, D. 1991. Scientific Fraud. *Am. Scholar* **60**;, p. 514.
9. See reference 1, p. xi.
10. ibid, p. 4.
11. ibid
12. ibid, p. 108.
13. ibid, p 143.
14. ibid, p. 144.
15. http://www.nap.edu/readingroom/books/obas/contents/error.html.
16. See reference 8, p. 514-515.
17. See reference 4, p. 11.
18. See reference 8, p. 506-507.
19. *Federal Register* **54**:446-451. August 8, 1989.
20. *Federal Register* **56**: 22286-22290. May 14, 1991.
21. Buzzelli, D.E. 1993. A definition of misconduct in science; a view from the NSF. Science **259:** p. 647.
22. see reference 8, p. 515.
23. Schachman, H.K. What is misconduct in science? *Science* **261**: p. 148.
24. See reference 21, p. 647.
25. See reference 8, p. 510.
26. Schader-Frechette, K. 1994. *The Ethics of Scientific Research,* p. 25. Rowman and Littlefield Publishers, Inc. Lanham, Maryland.
27. ibid, p. 83.
28. See reference 4, p. 15.
29. Yentsch C., and C.J. Snidermann. 1992. *The Woman Scientist - Meeting the Challenge for a Successful Career*. p. 145-159. Plenum Press, New York.
30. Reed, C.A. 2001. Drowning in a sea of refereed publications. *Chem & Eng. News,* p. 38.
31. See reference 8, p. 514.
32. See reference 4, p. 20.
33. See reference 26, p. 8.
34. See reference 1, p. 157.
35. ibid, p. 170.
36. See reference 2.