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How Risk Management Tools Can Inform Critical Thinking in Aid of Moral Commitment

This article explores the ways in which the quantitative and qualitative tools used by risk managers can help students think critically about issues. In particular, it identifies some of the quantitative skills used for risk assessment that can be taught and used in mathematics and science classes. It also examines the qualitative knowledge of governance structures, primarily acquired in social studies classes, and how these can be applied in analyzing solutions to the complex issues of this century and our future. Examples are given of the application of these diverse skill sets to such controversial issues as the use of nuclear technology, disaster response, and preservation of the environment. An interdisciplinary approach to the teaching of controversial issues is encouraged.

When writing *Teaching Controversial Issues* (Noddings & Brooks, 2017) last year, there was a lengthy chapter on technology and the environment that was omitted to save space. This article includes several ideas from that chapter and addresses their relevance to other articles in this special edition as informed by my professional interests in enterprise risk management. I share an educational background in mathematics and the sciences and personal interests in botany and marine biology with my mother, Nel Noddings. Consequently, we would both like to see an increased use of math and science classroom time for the discussion of controversial issues relevant to these areas of academic study. In this article, I claim that the moral issues arising from the proliferation of technology and the resulting impacts on the environment and social justice can be discussed directly in science and math classes, and math and science classroom time can be used to aid in the discussion of these topics as part of an interdisciplinary program. In addition, I discuss the tools used by risk management professionals that can help inform critical thinking in both the quantitative areas of probability and statistics and the qualitative area of governance models and that support the need for interdisciplinary study.

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A great deal of the content delivered in high school math and science classes is necessary to allow students to apply a reasoned approach to the controversial issues that abound in the development and deployment of technology. But, it is the passion for the subject matter with which the content is delivered that will motivate students to think critically about the issues and allow teachers of mathematics and the sciences to make a significant contribution to moral education. The direct posing of questions about the moral dilemmas found in the content can open many opportunities for character education and the discussion of related virtues. One of the problems with *character education* is that perceived virtues can be situationally dependent and new situations can arise for which the taught virtues may not be adequate. For instance, in reading *Character Lessons in American Biography* (White, 1909), none of the 31 virtues discussed would adequately describe the sentiments embodied in this 1910 quote from Theodore Roosevelt, which can be read when visiting his monument in the nation's capital: "The Nation behaves well, if it treats the natural resources as assets which it must turn over to the next generation increased and not impaired in value." Unselfishness is described in *Character Lessons* with reference to those around one today but the idea that people need be mindful of future generations is not captured by any of the 31 virtues presented, even though Theodore Roosevelt is an oft-cited exemplar! What virtues might be added to the list? Altruism, relational thought and caring, sensitivity and appreciation come to mind.

Many equate the development of technologies with progress and progress as positive. Is this always the case? What impact have the development of technologies and our moral behavior had on the environment – the food we eat, the water we drink and the air we breathe? What have been the positive and negative consequences of the development of nuclear technologies? Is nuclear power better than coal- or oil-fired electric generation? Better in what way? These are just some of the topics with controversial moral issues attached that lend themselves to discussion in science and math classrooms.

Technology and Our Global Environment

> To some, the word 'technology' conveys the specter of an overly mechanized society, a loss of contact with nature, a despoiler of civilization. Yet, without machines to take us into the sky, we would be as earthbound as elephants; without submarines and other specialized diving equipment, our ability to explore the oceans directly would be approximately equivalent to a dolphin's ability to glimpse its above-water realm. And without modern means of discovery and communication, there would be no hope of identifying the critical changes sweeping the planet and alerting the global community to growing threats to our species. (Earle, 1995, pp. 16–17)

In her book, *Sea Change*, Sylvia Earle (1995), noted marine biologist and technologist, discussed the positive ways in which technology can be used to help identify and rectify the negative changes that the human species has wrought upon the global environment, concentrating on those changes that impact the oceans that likely are the origin and sustenance of all life on the planet. Like Elizabeth Kolbert in *The Sixth Extinction* (2014), Earle felt strongly that in thier ignorance, humans could bring about their own demise:

> Far and away the greatest threat to the sea and to the future of mankind is ignorance. But with knowing comes caring, and with caring, the hope that maybe we'll find the Holy Grail of understanding, strike a balance with the natural systems that sustain us, and thus achieve an enduring place for humankind on a planet that got along without us for billions of years and no doubt could do so again. (Earle, 1995, p. xxi)

This is a beautiful example of the connection between knowledge, caring, and understanding.

In his book, *Catastrophe: Risk and Response* (2004), Richard Posner advocated for increased scientific literacy for all responsible citizens, but especially lawyers and politicians. When speaking of catastrophes, Posner was talking about events with potential human-extinction-level consequences, such as natural disasters (pandemics, asteroid strikes); scientific accidents (GMOs, artificial intelligence and nanomachines run amuck); and other man-made, both intended and unintended, disasters (bioterrorism, nuclear winter and global warming); but the risk management tools he advocated for can be applied to any risk affecting the quality and sustainability of life on our planet. Posner asserted that "the analytical and institutional challenges are formidable. In part this is because of the centrality of science and science policy to the catastrophic risks and their prevention" (2004, p. 8). He went on to say that "the challenge of managing science and technology in relation to the catastrophic risks is an enormous one, and if it can be met it will be by a mosaic of institutional arrangements, analytical procedures, regulatory measures, and professional skills" (p. 8). I assert that these same risk management skills are required in understanding many of the complex problems facing communities today, from adequacy of disaster response as discussed in Crocco's article (this issue) on Hurricane Katrina to the social justice issues of disproportionate environmental degradation in economically disadvantaged areas raised by Lejano and Ajaps (this issue).

Characterizing the current environmental problems as a result of the single and purportedly divisive issue of *man-induced global warming* detracts from a clear understanding of the predicament. Earle and Kolbert were careful to explain the integrated nature of environmental degradation and species loss on the planet as an ecosystem and the role that technology can play in recovery. This broader view allows one to look at three ideas important to the discussion of the moral issues here. The first of these is that often taking one premise in isolation—adding carbon dioxide to the atmosphere through the use of fossil fuels causes global warming to the planet's detriment—can make both discussion and solutions more difficult, because the problem is poorly posed in isolation, a good example of the necessity for interdisciplinary approaches. Second, the concept of consilience—that is, multiple streams of evidence from data and observation from many disciplines all pointing in the same direction—was used by Wilson (2006) to support the theory of evolution. This coming together of interdisciplinary streams of evidence is also the heart of scientific consensus on climate change. The third idea is that although creation of new technologies has caused much degradation, this does not mean that the creation of new technologies has no place in the discussion of solutions. As Kurlansky (1997) pointed out in his book, *Cod*: "But technology never reverses itself. It creates new technology to confront new sets of problems" (p. 133). Here is a wonderful book devoted solely to the history (and current demise) of a fish and its fisheries that have sustained our species for as long as we have recognized fish as food. This book could be read and discussed in a biology, history, English (for its quotes from Melville, Dumas, Dickens, and others) or home economics class (it even has recipes!) and in each case inclusion of the moral and global legal issues around sustainable fisheries would add valuable lessons on moral thinking and problem solving.

Probability and Statistics

Math and science teachers can clearly enhance the skills required to understand both the complexity and the significance of data that must be critically interpreted when discussing environmental and technological risks—the skills that Posner (2004) found lacking. In reading on both the pro and con sides of using nuclear energy for electricity generation, I was struck by both the use and misuse of mathematics in the arguments. On the con side, the work of Helen Caldicott, an Australian pediatrician who wrote *Nuclear Power is not the Answer* (2006) is filled with abusive uses of mathematics. Caldicott was nominated for the Nobel Peace Prize by Nobel Laureate Linus Pauling. In the early 1970s, she convinced Australia to sue France over atmospheric testing of nuclear weapons in the Pacific, which brought the practice to an end. She has been awarded 21 honorary doctoral degrees and named one of the most influential women of the 20th century by the Smithsonian Institution. Impressive credentials, but critical discussion of her book requires certain mathematical skills and tools to understand the issues presented.

The questions and topics for moral consideration regarding the uses of nuclear energy are clearly relevant to today's students studying environmental science, biology, physics, health, or even social studies; but what of mathematics? Thinking critically about these cannot be accomplished without an understanding of probability and statistics and the proper application of this branch of mathematics that is little taught and even less well understood by the general populace. One of my favorite books, written in 1954, is Darrell Huff's *How to Lie with Statistics*. I have long wished that someone would update this book with more recent examples. The debate and propaganda on both sides of the *green-ness* and safety issues around nuclear reactors could supply updates for every chapter of Huff's book from sample bias to causal relationships. Two additional considerations for math and physics teachers to help students sort fact from spin and outright fiction concerning nuclear issues are the proper definition and equivalence of various units of measurement and the scales of measurement related to very large and very small numbers.

In reading Caldicott's (2006) book, I had to break out pencil, paper, and calculator to work out for myself the relationship between petajoules and terawatt-hours (TWh), two different units of energy that she used interchangeably while purportedly adding up fossil fuel use (which generates CO_2) in the life-cycle of nuclear generation the *greenness* of which she finds questionable. At one point, she said that the

> energetic costs of the nuclear fuel cycle just from mining the ore through reactor construction to dismantling the reactor, without even assessing the energy costs of storage and transportation of radioactive waste, the total energy debit comes to approximately 240 petajoules (24 million billion joules). The construction and implementation processes involved in a gas-fired plant require only one-tenth that amount—24 petajoules—to produce the same amount of electricity. (Caldicott, 2006, p. 16)

There are two problems here. First, a petajoule is a million billion or 10^{15} joules (one followed by 15 zeros!). Without context, how are we to understand such large numbers? Numbers of this magnitude are inherently scary when we have no frame of reference with which to visualize them. When one knows that 240 petajoules is equivalent to about 67 TWh—or roughly the amount of energy generated by a 1,000-megawatt nuclear power plant over 8 to 9 years—one can begin to grasp what the numbers are saying. It helps further to note that the average US homeowner uses 10.9 megawatt-hours per year, so that a 1,000-megawatt nuclear power plant can provide energy to more than 660,000 residential customers in one year. The second problem is that Caldicott (2006) was comparing apples and oranges here. Notice that for the nuclear plant, she included all of the costs of the fuel cycle (mining, milling, enrichment,and transportation) as well as plant construction and dismantling; for the gas-fired plant she mentioned only construction and unspecified "implementation processes."

Her flawed arguments against the *green-ness* of nuclear power, which appear early in the book, detract from her credibility in the later sections on safety where, as a physician, one hopes she is more knowledgeable; but here again she uses large numbers without context to frighten. Although she was quick to say that a petajoule is 10^{15} joules (a very big number), she neglected to mention when speaking about radioactivity in milk following the accident at Three Mile Island, that a picocurie is 10^{-12} curies (1 picocurie is .000000000001 curies, a very small number). Instead, she reported concentrations between 3,000 and 21,500 picocuries/liter of milk. She did not give meaningful context for the numbers when she said that, "if a one-year old child drank a liter of milk containing 21,300 picocuries/liter, she would receive a dose of about 0.3 rems to her thyroid, which could result in thyroid cancer years later" (Caldicott, 2006, p. 70). The missing context here is that 0.3 rems is equivalent to the radiation received from about eight dental X-rays or three times the annual exposure from the naturally occurring background radiation in the Harrisburg area. Nor does she help the reader by explaining such things as the difference between measuring radioactivity (curies) and exposure dosage (rems); that a timely dose of potassium iodide would prevent the child's thyroid from taking up the exposure at all; or that a state health registry that tracked 30,000 people for 2 decades after the accident found no evidence of any effects attributable to radiation exposure.

For a comprehensive exploration of nuclear power generation from uranium mining to the storage of nuclear waste and the reprocessing of fuel without making weapons-grade plutonium available to terrorists, I turned to the work of Gwyneth Cravens, *The Power to Save the World: The Truth about Nuclear Energy* (2007). I am not recommending or endorsing nuclear power here or suggesting that teachers should do so. Rather, the aim is to provide resources and tools to foster understanding and critical debate. It cannot be ignored that many people (like Caldicott) have difficulty separating the issues of nuclear weapons proliferation from nuclear power generation and yet, not one of the extant nine nuclear powers derived their weapons capabilities from reactors designed for power generation. Learning about the history and science of these two related technologies will allow students to separate the moral issues involved.

Cravens (2007) shared the journey she undertook to educate herself about all aspects of nuclear power when she realized that she held fears based on a Cold War childhood, experienced by most US baby-boomers, but with little real knowledge on which to base these fears. The book is, in large part, a continuous conversation with a guide and mentor, her Virgil for the journey, D. Richard Anderson, Ph.D., referred to by friends and colleagues as Rip.

> Conversant with deep time—the remote past and the planet ten thousand years from now—and with the universe of risk and consequence, he [Rip] had acquired an international reputation in the fields of probabilistic risk assessment, environmental health, and nuclear safety. His colleagues told me that he was highly respected for his original thinking and the comprehensive sensibility he displayed when managing large programs. To this day, he encourages those who work for him to do their best to make the hypothesis under scrutiny fail. Those who have worked for him tell me that this maverick imperative has made for the best science they've ever done—and they speak of his contribution to Big Science, his uniquely comprehensive approach to finding solutions, his unwavering respect for scientific objectivity, his status in his fields of expertise, his willingness to take unpopular stands in the scientific and technical communities, and his refusal to compromise with prevailing notions unsupported by science. (Cravens, 2007, pp. 7–8)

This description of her guide for the journey is important to this conversation for several reasons. First, it reinforces the concept of studying big problems from a multidisciplinary approach. Second, in referring to his comprehensive sensibility when managing large programs, it promotes the need for integration and focus when using multidisciplinary approaches. Last but not least, for those already mathematically inclined, the use of probabilistic risk assessment (PRA) when tackling large problems with multiple variables is a key understanding required to critically evaluate alternative solutions, particularly when individual lives are at stake but especially when the health of our whole planet may be affected.

> "In many cases, PRA identifies that uncertainty to a great degree," Rip continued, "and tells you how to minimize the risk in your design. Probabilistic risk assessment is about the future. You take a range of scenarios, you calculate how likely they are to occur by themselves or in combination with others, and if they do, what the consequences will be."
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> He pointed to the bell curve. "What is the worst case, and how many features, events, and processes would work together to produce it? And how likely is that worst case to occur? What's the likeliest, there in the middle part? You figure out what you really need to pay attention to and where to put your dollar. Probabilistic risk assessment changed my life. After I learned it I thought differently about everything." (Cravens, 2007, p. 145)

A few lessons in creating decision trees, assigning probabilities and assessing expected outcomes, and performing cost benefit analyses could easily be incorporated in a math class in support, for example, of an exercise in the social studies curriculum to simulate response to a disaster. Such an exercise could include guest appearances by government and community leaders, emergency responders, and relief organizations, and allow for role-playing by students across a wide variety of future career possibilities. The exercise could focus on a local problem of relevance to the school's community—for coastal areas, a flood; for poor urban areas, a pandemic; and for communities close to a power plant or major industrial facility, an explosion, fire, or release of toxic pollutants. By allowing students to focus on the contributions that they could make in such situations, as well as exposing them to the thought processes and potential action plans of responsible parties, they will better understand the meaning of their learned math concepts, the role of informed leadership and the need for both individual and group participation in a functional democracy. This last is nicely explored in Libresco's (this issue) use with younger students of the Dr. Seuss classic, *Yertle the Turtle*.

Governance

This brings me to the other set of tools used by enterprise risk managers: the governance tools referred to by Posner (2004; institutional arrangements, regulatory measures, and science policy). In *Sea Change*, Earle (1995) referred to the earlier works of Garret Hardin on the tragedy of the commons (land used in common, for example, village pasturage) when discussing the global moral, ethical, and legal issues of sustainable fisheries. In a chapter titled "No Free Lunch," Earle (1995) began with an old Yarmouth sea chanty:

> The farmer has his rent to pay,
> Haul you joskins, haul.
> And seed to buy, I've heard him say.
> Haul, you joskins, haul.
> But we who plough the North Sea deep
> Though never sowing, always reap,
> The harvest which to all is free…
> Haul, you joskins haul. (p. 167)

In discussing the issue of ownership of the sea and its resources, people meet the tragedy of the commons head on; if no one owns property held in common (the harvest which to all is free) then each user is incented to take as much as possible —before someone else beats him to it. If people in the United States don't catch the fish, Norway or Japan will do it!

In *Governance Reimagined* (2012), risk manager David Koenig discussed the need for a polycentric form of governance that is both distributed and networked. He referred to the work on management of the commons by Elinor Ostrom who won the Nobel Prize in Economics in 2009. In the tragedy of the commons, it is assumed that without government intervention, depletion of the commons will occur; that users of the commons are trapped in a type of Prisoner's Dilemma.

> Ostroms's research found that when agents are constrained in this game in the way in which the classic Prisoner's Dilemma is played—they are not allowed to communicate or to plan future decisions in the game—this negative outcome is indeed sure to be realized.
>
> However, Ostrom's research also found that when cooperation among agents is allowed, when they have repeated face-to-face communication, and particularly when the agents have the ability to change how the game is played, they can easily break groups out of this trap of commons abuse. In fact, when these conditions prevail, self-governance structures are extremely successful in increasing returns, not depleting the resource. They are substantially more efficient than those overseen by some centralized governor that is distant and remote to the users of the resource. (Koenig, 2012, p. 203)

Koenig would say this type of cooperation, and the increase in long-term value that it creates, is fostered by the networking of stakeholders with differing interests to create boundary and choice rules and self-governing systems for the monitoring and sanctioning of rule breakers. The distributed aspect of governance here is represented by the proper allocation of authority and resources in the creation of an overarching set of governing bodies and high-level policies. This is very much what is required to achieve the "Caring State" described by Lejano and Ajaps (this issue), where authority is appropriately distributed to local entities capable of face-to-face interaction with a network of community interests.

In summary, the discussion of controversial issues such as global warming, nuclear energy, or fisheries management in science and math classes can provide an opportunity for students to think critically, build character, and develop moral commitments. The quantitative risk management skills acquired through the study in mathematics and science classes of probability and statistics and the qualitative understanding of governance structures developed at an early age and enhanced in social science classes and interdisciplinary programs are necessary basics for solving the increasingly complex problems that humanity faces today and into the future.

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Additional Resources

1. Conant, J. (2002). *Tuxedo Park: A Wall Street tycoon and the secret palace of science that changed the course of World War II.* New York, NY: Simon & Schuster.

Books like this one help students understand that science is a human endeavor and that scientific and technologic advancements have consequences (both good and bad) that raise moral issues. This could be read in a high school physics or chemistry class in conjunction with concurrent studies in a social science class on the history of World War II.

2. Dr. Seuss. (1971). *The Lorax*. New York, NY: Random House.

In 2012, based on a 2007 online poll, the National Education Association named *The Lorax* one of its "Teachers' Top 100 Books for Children." This is an introduction for children to the potential for environmental degradation that may be caused by unregulated industry. There is also an animated movie of the same name based on the book. Reading or viewing and discussion could be enhanced by a proactive activity such as planting a tree.

3. Wilson, E. O. (2016). *Half-Earth: Our planet's fight for life*. New York, NY: Liveright.

Set aside half the planet as a nature reserve. This is the bold solution proposed by renowned naturalist E. O. Wilson in his latest book, which documents the imperative of biodiversity and species preservation. He gives a profound sense of urgency to the problem while maintaining an optimistic view that it is not too late to adopt potential solutions.