Helping Students Understand Risk

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ABSTRACT

Despite the central role of risk assessment in analyzing and making decisions about many environmental issues, most people are poorly equipped to understand key concepts about risk or apply them successfully. I present three class activities in which students develop a better appreciation for the magnitude of a one in a million increased risk of death, consider the difference between perception and quantified risk, and gain expert knowledge in public attitudes and methods of conducting opinion surveys. The activities use an aquarium of doughnut sprinkles to visually depict risk magnitude, a calculation of increased highway fatalities and fuel consumption based on patterns of work commutes, and a survey conducted by the students to ascertain risk attitudes and willingness to pay (WTP) for environmental protection.

Understanding risk is key to analyzing environmental issues, and most environmental science textbooks include a section on risk (Chiras, 2001; Cunningham et al., 2003; Miller, 2005; Raven and Berg, 2004). At both a personal and societal level, citizens need to be able to comprehend the disparate claims and studies about environmental and other hazards reported in the media. Society makes decisions about shared (public) risk, including environmental assessments and environmental laws, through our political and economic institutions. Debates about how to store radioactive wastes, how to address global climate change, or whether to require costly remediation of groundwater contamination, all necessitate a discussion about risk. Unfortunately, these discussions are often heated and lacking in effective scientific input (Stern and Fineberg, 1996). The public usually lacks necessary information and most people lack comprehension about the technical aspects of the issues (National Research Council, 1994), or even a basic concept of "safety" and "acceptable risk" (Gots, 1993).

Tomorrow's leaders and decision makers are today's students in our environmental science classes. They need to advance beyond a layperson's understanding of risk and become experts, able to properly analyze the various issues they study. Richard (1993) persuasively argues for incorporating risk literacy in environmental education, and Chiras (1982) provides a conceptual framework. In this article, I present three class activities to help students better understand how we measure, comprehend, and evaluate risk, and use risk assessment in decision making.

One Million Sprinkles

One of the most significant difficulties in risk assessment is an appreciation for the magnitude of the common benchmark unit: an increased risk of death of one in a million. Such a number is abstract and difficult to comprehend. I help students overcome this difficulty with an in-class exercise.

As we begin the unit on risk, I display a glass aquarium containing one million brightly colored sprinkles, the type used to decorate cookies or doughnuts. The sprinkles occupy a space 22 by 15 by 46 cm, equivalent to a volume of 15 L (4 U.S. gallons); it was estimated at one million by a trusted work-study student who counted and weighed a representarive sample, then measured out the appropriate mass into the aquarium.

I explain that the aquarium contains one million sprinkles; 999,999 of the sprinkles are harmless, but one is treated with a deadly toxin that causes immediate death if eaten. The sprinkles have been thoroughly mixed, so any one of them could be the toxic one. I then ask, "How much money would I need to pay you to eat one sprinkle?" It normally takes little time to obtain many responses (always voluntary in my class); the range of responses often spans tens of thousands of dollars. A few students will pointedly suggest that assuming such a risk of death is immoral.

At this point, it is usually helpful to refer to an introductory environmental science textbook. I use Cunningham et al. (2003), which includes a table (based on Allman, 1985) listing many ordinary activities (smoking 1.4 cigarettes, traveling 16 km [10 miles] by bicycle, eating 600 mL [40 tablespoons] of peanut butter), which each increase the risk of death by one in one million. We then discuss how people assume risk in their everyday lives, including environmental hazards such as nuclear power or second-hand (environmental) tobacco smoke.

This sprinkle exercise has several aspects I find useful in teaching about risk. First, it allows students to visualize a one in one million risk. Such ability puts my students in a very small group of experts who truly understand this concept. I explain to students that this is a profound experience because

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Abbreviations: WTP, willingness to pay.
humans process so much information visually; truly, "seeing is believing." Second, by placing a dollar amount on assuming the one in one million risk (price to eat a sprinkle), they are unwittingly placing a dollar value on their own lives. Repugnant as this may seem, it is routine in environmental assessments to conduct cost/benefit analyses, and placing a dollar value on human life is part of the accounting. I discuss several other ways this is accomplished (e.g., value of life insurance policies, or calculations of lost wages over a given number of years) and at that point, students are highly engaged in the discussion!

**Highway Fatalities**

A practical application of risk estimates is to evaluate proposed alternatives in environmental assessment or other planning. The city in which I reside (Pella, IA; population 10,000) has identified a need for additional affordable housing, and has sought local home builders to address this issue. To date, workers in our local industries simply commute from outlying areas where housing is affordable.

But at what cost is this done? In a class exercise on urban planning, students calculate the number of deaths resulting from this forced commute. I called the human resources office of the largest local employer, obtaining information about average commutes for the factory workers. From the World Wide Web (www.nhtsa.com/people/Crash/crashstatistics; verified 22 Dec. 2005), I obtained estimates of fatalities per miles driven. The average for both my State (Iowa), and the USA overall, is 1.6 deaths per 160 million km (100 million miles) driven. It is then a simple calculation to determine how many workers will typically die over a time period (say, 10 years) because they must commute. I believe the implications are self-evident and sufficiently grave; I do not elaborate in class.

However, in addition to this "human cost," students calculate the amount of gasoline consumed from this commuting (based on rough assumptions about fleet fuel efficiency along with the commute distance obtained from local employer). Similarly, nationwide figures are available for the mean U.S. commute: 19.0 km (11.8 miles) each way in 1995 (ORNL, 1995) and a mean fuel efficiency of 8.9 km/L (21.0 miles/gallon) (USEPA, 2005).

Optional activities with this exercise could also include having students visualize the amount of gasoline consumed by dividing the figure by 49,000 L (13,000 gallons, a typical gasoline tank truck capacity) to estimate the number of such trucks filled with gasoline to fuel the commute. Also, a discussion of fuel efficiency may be warranted. Students might be surprised that the overall fleet fuel efficiency is actually lower in 2005 than in 1985 because more household vehicles are trucks and sport-utility vehicles (USEPA, 2005).

**Risk Attitudes Survey**

To examine the social, cultural, and psychological factors involved in how people understand risk, I use a survey exercise designed to separate actual (measured) risk from risk perception. Further, in the exercise students act as social scientists as they utilize and critique a survey instrument and analyze responses. While introducing the survey activity, I ask students to state three hypotheses about how the respondents will answer. I warn them that our results will have meaning only to the extent that we are aware of, and try to control, sampling bias.

I provide survey forms and instruct students to complete the activity within a few days. Each student is required to administer the survey to three people, none of whom may have previously taken the class. Nearly all the survey respondents are fellow college students, although this is not stipulated in the instructions. Having a few respondents who are not college students adds an interesting perspective to the activity during the subsequent class discussion. Completing the activity within a single week allows the presentation of results and subsequent class discussion to occur while memories of the activity are still fresh.

Recently, I converted this activity from a paper-based survey form to an online version using the Survey Manager function of the Blackboard Learning System software, Version 6.2 (Blackboard, 2005). Advantages to this change include saving paper and dramatically reducing the time spent by the instructor entering data into the computer for analyses.

This aids in achieving the target of a 1-week timeline.

Either paper-based or online, the survey includes four questions (Table 1). The first asks respondents to rate our government's level of environmental regulation. Such a question is typical of the public opinion polls described regularly in the news media, and gives both students and respondents a point of reference. In the past I have attempted to correlate the answers according to respondent's gender, academic major/interest area, hometown size, and other factors. The results have proven inconclusive and I have abandoned that portion of the exercise. Similarly, Riechard and Peterson (1998) surveyed precollege students and found a gender difference, but no significant difference in scoring based on respondent's socioeconomic status.

The second question uses WTP (willingness to pay), a standard metric to quantify how one values certain environmental amenities, and adds economic data to cost/benefit analyses in environmental assessments; see Wanki Moon and Balasubramanian (2003) and Hagiwara et al. (2004) for examples. In the past, I have used WTP for different fish species (e.g., compare value of a single minnow, bass, and trout). This comparison can be useful as we discuss water quality, because our state government levies
Table 1. Survey questions given by 45 NASC 120 (Introduction to Environmental Science) students at Central College to 135 respondents, spring 2005.

Survey questions

1. How do you rate our government's environmental laws and regulations?
   a. Clearly too weak, not protecting enough
   b. Should be a bit stronger
   c. Just about right
   d. A bit too strict
   e. Clearly too strict, and should be relaxed

2. How many more (if any) additional tax dollars would you pay PER YEAR, if it would effectively protect Iowa's endangered species, keeping them from going extinct?

3. In your opinion, which of the following is most likely to happen in the USA?
   a. An accident at a factory releases a cloud of poisonous gas, killing hundreds
   b. A nuclear power plant releases radiation, killing hundreds
   c. Global warming causes a summer heat wave, killing hundreds
   d. An exotic disease enters the USA, is spread by mosquitoes, killing hundreds

4. In theory, any of the following activities could result in your death. Rank these risks in decreasing order, with number one (1) being the highest risk, to 6 being the lowest risk. Each activity happens only one time (not once a day or once a month etc.)
   a. Living for 5 years, just outside a nuclear power plant
   b. One chest X-ray
   c. Flying 1000 miles in an airplane under normal conditions
   d. Driving 150 miles in a car under normal conditions
   e. Drinking half a bottle of wine
   f. Smoking a single cigarette

Fig. 1. Responses to Question 4 of the risk survey. "Rank these issues in decreasing order, with 1 being the highest risk to 6 being the lowest." Data from 135 respondents to NASC 120 (Introduction to Environmental Science) survey at Central College, spring 2005.

that respondents indicate a knowledge of "conventional wisdom" to indicate that driving is more dangerous than flying, and rank accordingly (Fig. 1). Other responses vary considerably with nuclear power rating high, and respondents struggling to rate smoking risk. Past experience has taught me that it is imperative that students administering the survey make sure the respondents understand that each event in Question 4 is a discrete, one-time event. As expected, these questions provide an excellent opportunity for class discussion about factors affecting risk perception.

We begin our analyses by examining the results of each question in turn. I invite students to describe any problems respondents had understanding or answering the questions.

In a lecture before this exercise, I suggest that total risk magnitude is a product of risk probability and risk severity. During the present exercise, I remind students of this concept, and point out that we are ostensibly asking respondents their opinions about "how likely" an event is (probability), which in reality is a statistic, not a matter of opinion. Therefore, responses really indicate a subject's intuitive understanding of risk. I usually ask two questions to engage discussion, and to allow students to steer the discussion with minimal input from me: (i) Why do we see the patterns in responses of probabilities in Question 4, and (ii) How does the intuitive understanding of risk, demonstrated here, influence personal and societal decision-making? If time permits, it may be interesting to separate public/societal risks (as in Question 3), from individual/personal risks (most of the Question 4 choices).

I ask students to comment on respondent's reactions to Question 4. In most cases, students have pointed out that the unfamiliar (nuclear power) is more feared than the familiar (X-rays). They usually
suggest that risks we take voluntarily (e.g., drinking wine or smoking) are less feared than involuntary risks such as flying. Sometimes students report that the "size" of the activity may be important: flying 1000 miles simply appears to be a more significant undertaking than smoking one cigarette.

Students are surprised that all of the risks in Question 4 have the same magnitude. They agree with the pattern of responses observed (i.e., the results are indeed intuitive). The psychology of risk is complex, but students usually understand that a combination of emotional anxiety and logic interact to produce predictable patterns. Ultimately, they indicate that policy decisions will necessarily be shaped by this psychological dynamic.

In the classroom discussion of the survey and results, we revisit the methodology used including the survey instrument itself. Most agree that the form uses fairly neutral language, and that considering the wording is crucial to interpretation. I also ask students to speculate how the respondents would answer if I were asking the questions instead of them, or if respondents had been told that the survey was for a political science, business, or other class. I ask how the results might differ if respondents lived in a large urban neighborhood or in a retirement community. I leave plenty of class time to discuss these issues and stress critical evaluation of the exercise itself. My bottom line is that when it comes to surveys, everything matters: who is asking, who is asked, the wording and ordering of the questions, and so forth.

Conclusions
These activities are mentioned frequently in end-of-semester student evaluations as being memorable and engaging. It is clear to me from the tone of later class discussions, and from responses to open-ended questions on exams, that students' sophistication in analyzing risk has markedly improved. This instructional approach starts from erroneous "common sense" beliefs and then challenges students to think both quantitatively and critically.

Instructors wishing to incorporate these or similar activities in their courses might consider a strategy by which risk (and decision making) is a thread running through several class units. Risk analyses can be productive in discussions of toxicology, global climate change, nuclear power, and many other topics. It should ideally be covered before a unit on economic analyses to inform that discussion.

References