Communications

The Role of Statistical Literacy in Decisions about Risk: Where to Start

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For some time now, there has been considerable discussion among sociologists and educational researchers about adolescents' decision making in situations of risk Of concern to researchers are drug abuse of various sorts, unprotected sex in the face of the HIV/AIDS threat, deaths of young males in car accidents, sunbaking leading to high incidence of skin cancer, youth suicide and dietary habits which risk health problems in later life (e g. Pfeffer, 1989; Plant and Plant, 1992). Research has shown that risk-taking behaviour may be related to adolescent feelings of vulnerability or invulnerability, levels of self-esteem and perceptions of the locus-of-control for events in the adolescents' lives (Mann and Harmoni, 1989) Research also has shown, however, that in areas such as the threat of HIV/AIDS, education programs which increase knowledge levels in students are not always accompanied by a reduction in risk-taking behaviour (Roscoe and Kruger, 1990).

In the 1990s, curriculum designers have taken note of the warnings from research about risk In *A Statement on Health and Physical Education for Australian Schools* (AEC, 1994), for example:

> Students examine the concept of risk, including real and perceived risk, and how this relates to different situations. They identify factors that influence risk-taking, and explore how inappropriate risk-taking presents dangers. They learn about the causes and consequences of different behaviours and the potential risks to safety related to, for example, substance use, sexual practices, participation in physical activities, and road behaviour (p 14)

In this *Statement*, however, there is no mention of the mathematical aspects of evaluating risk.

Both research and the health curriculum in the area of adolescent risk appear to have ignored the potential contribution of students' understanding of statistics or chance to their capacity to draw reliable conclusions about factors influencing behaviour. The school mathematics curriculum, however, has begun to take note of risk in the wider definition of numeracy required for life experiences. Thus, in *A National Statement on Mathematics for Australian Schools* (AEC, 1991), it is asserted that:

> Making informed choices will often require a general understanding of the mathematics underlying the analysis of costs and risks (p 6)

In considering research and teaching programs involving risk, two perspectives are essential The first involves the social and psychological pressures which affect individuals in making decisions; these may include factors such as self-esteem and locus-of-control The second perspective relates to the mathematical assessment of the degree of risk involved in a situation based on the information available In this context, there has been no study of students' statistical understanding. In making behavioural choices, there are likely to be interactions between these two aspects of risk analysis.

Sandman (1993) has attempted to bridge the gap between the sociological and numerical aspects by proposing a model for perceived risk, seeing it as a function of hazard (from a statistical perspective) and outrage (from a social or psychological perspective),

risk = f(hazard, outrage).

In justifying the importance of this distinction between hazard and outrage, Sandman presents the following argument:

> If you took a long list of hazards and rank-ordered them by something such as expected annual mortality [...] and then rank-ordered the same list by how upsetting the various risks are to people, the correlation between the two rank orders would be approximately 2 [...] a depressing 4 percent of the variance. In other words, the risks that kill people and the risks that upset them are completely different. [...] What we need to figure out is why that is true. (p. 2)

While one may argue about the 'objective' criterion set by Sandman in ranking risks, the point is nevertheless well taken that objective and subjective evaluations of perceived risk will differ.

Sandman works with government and private agencies that have what they consider are low-probability hazards but are faced by high levels of public outrage; examples include dioxins in pesticides or radium-contaminated soil from slag deposits. In Sandman's context, outrage encompasses: "all the things that people are worried about that the experts ignore" (p 7). In the education of adolescents to handle situations of risk, for example in relation to certain drug-taking or sexual habits, the components of the equation are the same but the emphasis is different. In schools, the educating agency considers that the hazard of inappropriate behaviour is high but the public outrage on the part of adolescents is low. The desire is to create social outrage which will affect individual behavior choices. Sandman's model is useful to conceptualize the factors which contribute to both kinds of difficult risk situations - those with high hazard and low outrage and those with low hazard and high outrage

While suggesting the two components of risk are hazard and outrage, Sandman focuses his attention on the latter, describing 20 aspects of outrage - variables which are associated with public misperception of risk. Some of these include whether the risk is voluntary or coerced, whether the hazard is natural or industrial, whether the hazard is familiar or exotic, whether the outcome is dreaded or not dreaded, whether the risk is controlled by the individual or by others, and whether the outcome is chronic or catastrophic (*op. cit.*, p. 13 and all of Chapter 2). These characterizations are useful for considering both high- and low-hazard contexts. Sandman sees the hazard component as the objective part of the equation, composed of a quantified probability of an undesirable event occurring, together with a factual understanding of the context within which it applies. This is the component with which a level of statistical literacy required for interpretation of information presented can be associated and he, like others, appears to ignore this need

When conducting research or planning intervention programs, both hazard and outrage must be taken into account. Assuming that the sociologists and psychologists can address the components of public and personal outrage through their long established study of adolescent risk-taking behaviour, attention of researchers should turn to the mathematical aspects In Watson (1997), I have suggested a hierarchy which may assist in understanding concepts necessary to interpret hazard The hierarchy involves three tiers:

(1) having knowledge of basic statistical terms;

(2) recognizing these and interpreting them in applied contexts;

(3) being able to question unrealistic claims made by the media or others.

Situations where adolescents encounter risk provide a timely context in which to consider this hierarchy.

Tier 1: Is there the basic understanding required to interpret the probabilities associated with risk statements?

Tier 2: Are risk statements understood in the context and under the conditions presented? Do students understand associations among empirical data upon which such statements are based?

Tier 3: Can adolescents question claims when it is appropriate to do so, regarding the links among empirical data, method of presentation and statement of risk?

Not a great deal of research has yet been done on these questions. Research into students' basic understanding of chance and their general statistical literacy skills, however, indicate that for many adolescents the answer to all of the questions is likely to be 'no'

For Tier 1, there is evidence that many students have an "anything can happen" view of chance situations or think of probabilities in qualitative rather than quantitative terms (Watson *et al.*, 1997) Interpreting statements involving relative likelihood under differing conditions in various contexts (Tier 2) also creates problems for many students A sample of over 300 Grade 9 students was asked to interpret the meaning of the four conditional claims in the following newspaper article about smoking and wrinkles, by writing each in "if ..., then ..." form.

> A study found that those who smoked a pack of cigarettes a day for less than 49 years doubled the risk of premature wrinkling.
>
> For more than 50 years, the risk was 4.7 times greater than those who do not smoke ...
>
> He said he was not sure if the wrinkling could be reversed if people quit smoking ...
>
> "'You're going to be old and ugly before your time if you smoke', may be just the message that leads them to throw away their cigarettes for good", he said.

Of this group, 64% responded appropriately for the first sentence, 46% for the second and 44% for the third. For the last sentence, where two conditional constructions are involved, 28% correctly interpreted the complex conditional claim that change of behavior was conditional on understanding the quoted message. Interpreting cause-effect claims is another difficulty, both in terms of understanding in context (Tier 2) and questioning claims (Tier 3). The same sample of students was asked what questions they would pose to the researcher discussed in the following newspaper extract

> Twenty years of research has convinced Mr Robinson that motoring is a health hazard. Mr Robinson has graphs which show quite dramatically an almost perfect relationship between the increase in heart deaths and the increase in use of motor vehicles.

Only 20% could adequately question the cause-effect relationship implied in the report.

Sandman's model brings attention to the quantitative and qualitative variables which are required to assess hazard and make decisions in situations of risk. This, together with the skills of statistical literacy required for quantitative understanding, should add a new dimension to research into the factors associated with adolescent behaviour in situations of risk The added complexity of studying interactions with other variables related to objective knowledge of the context and subjective beliefs associated with personal or public outrage should not stop researchers looking into the problem. Likewise, exploration of the relationships that exist between perceptions of hazard and of outrage should be part of risk education programs for adolescents: as well, programs should include specific skills of statistical literacy. It may be that experiences intended to improve statistical literacy which are embedded in social contexts such as the examples given here are more motivating and successful than traditional mathematical contexts of spinners and dice.

While many in health education may see educating for risk as a sequence of warnings about negative outcomes of certain behaviors – "don't take the risk" – there is also the important issue of educating students to make intelligent decisions about risk as presented in any context in society. Students need to know not only why they should not engage in unsafe sex practices or not spend hours unprotected in the sun at the beach, but also how to judge risk statements about environmental disasters and nuclear accidents This makes statistical literacy in relation to risk the responsibility of many subject areas in the school curriculum. A balanced approach which teaches about both high risk–low outrage and low risk-high outrage situations may help create the credibility to get the appropriate messages across. Research should explore both aspects and may contribute insights to inform curriculum planners and teachers.

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Divisors and Quotients: Acknowledging Polysemy

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Durkin and Shire (1991) discuss several different types of lexical ambiguity, and suggest that by attending to lexical ambiguity:

> we can identify the basis for particular misinterpretation by pupils, and hence develop teaching strategies that circumvent or exploit such tendencies. (p. 73)

With respect to the mathematics classroom, they mention *polysemy* as one of the principal concerns, namely certain words having different but related meanings. Words such as 'combinations', 'similar', 'diagonal' or 'product' are examples of polysemous terms. The lexical ambiguity in these words is between their basic, everyday meanings and their meanings in the 'mathematics register' of the language, that is, their specialized use in a mathematical context. When a word means different things in different contexts, the intended meaning is usually specified by the context, including when different meanings of the word are presumed in everyday context and the mathematics register.

When the intended meaning of the word in the mathematics register is not available to a student, a sense is often 'borrowed' from an everyday situation. The word 'diagonal', for example, used by a teacher in a geometry class, would probably refer to a segment connecting two vertices of a polygon. An insightful dialog about diagonals is presented by Pimm (1987, pp. 84-85), where a 13-year-old child interprets 'diagonal' as a "sloping side of a figure relative to the natural orientation of the page".

Polysemy can also occur *within* the mathematics register itself, and context usually provides the primary identifier here as well. For example, the word 'operation' means one of the four – addition, subtraction, multiplication or division – in an elementary school classroom, while the same word means a function of two variables in a group theory course. We talk about the number 'zero' in elementary or middle school, and 'zeros of a polynomial' in an analysis course. 'Congruence' has different meanings in geometry and number theory. The meaning of a 'graph' depends on whether one is thinking about graphing functions in grade 10 algebra or graph theory.

'Divisor' and 'quotient'

I would like to focus here on two instances of polysemous terms: 'divisor' and 'quotient'. In my view, they deserve special attention because the lexical ambiguity presented by these terms is not *between* their everyday and mathematical usages, but arises *within* the mathematical context, within the mathematics register itself. In addition, as you will see, the context does not help in assigning meanings in this case. Both meanings for these words appear within the same 'sub-register' – the elementary mathematics classroom and a mathematics course for elementary school teachers.

'Divisor' has two meanings in the context of elementary arithmetic:

(i) a *divisor* is the number we 'divide by';

(ii) from a perspective of introductory number theory, for any two whole numbers a and b, where b is non-zero, b is a *divisor* (or *factor*) of a if and only if there exists a whole number c such that $bc = a$.

The latter is a formal definition of a divisor in terms of multiplication. Formulated in terms of division, b is a divisor of a in this sense if and only if the division of a by b results in a whole number, with no remainder.

'Quotient' means:

(i) the result of division;

(ii) in the context of the division algorithm, the integral part of this result.

Examples of discord 1: the classroom

What is the quotient in the division of 12 by 5? There was no consensus about its value among my students in a 'Foundations of mathematics' course for pre-service elementary teachers, and suggestions included 2 (with a remainder of 2), 2 2/5, 2.4 and 12/5. Trying to determine the solution in a democratic way, we took a vote: 19 students voted for 2, 37 students voted for 2.4, 2 2/5 or 12/5 (a combined count after agreeing that these were essentially different representations of the same number) and 9 students abstained. I purposefully ignored the lonely, uncertain voice from the audience who claimed: "It matters what you mean by a quotient, doesn't it?"