PREPARING FOR DIVERSITY IN STATISTICS LITERACY: INSTITUTIONAL AND EDUCATIONAL IMPLICATIONS

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Improving the public's understanding of statistical information requires that producers or reporters of statistical messages are aware of: The nature of people's statistics literacy, The factors that affect the difficulty of statistics-related messages, The existence of individual or group differences in statistics literacy; and The information needs of different target audiences. Implications are discussed regarding the need to prepare different types of communicative products and formulate strategies for dissemination and public education.

INTRODUCTION

Increasing emphasis is placed in recent years on empowering citizens from all walks of life to function effectively in an information-laden society (European Commission, 1996). Statistical information, produced by an increasing number of public agencies, non-profit organizations, and commercial companies, has a special role in the information fabric of modern societies, as it enables people to be aware and capable of reacting to phenomena of social, political, economic, and personal importance. Wallman (1993), in a 1992 ASA Presidential address, emphasized the importance of strengthening understanding of statistics among all population sectors, in part due to several barriers, i.e., misunderstandings, misperceptions, mistrust, and misgivings, that people have towards the value of statistics in public and private choices. However, the interest in improving the public's ability to comprehend statistical information should not be limited to those who teach statistics or are interested in reforming statistics education. Producers or reporters of statistical information have important responsibilities in this regard.

We argue that producers or reporters of statistical information who want to be effective in transmitting informative messages that can be of value to the full spectrum of their constituents should prepare different types of communicative products and formulate long-term strategies for dissemination and public education. The design of products and strategies needs be based on sensitivity to and understanding of four issues: 1). The nature of the skills and beliefs that underlie or enable people's statistics literacy; 2). The factors that affect the relative difficulty of statistics-related messages and tasks; 3). Existence of individual or group differences in statistics literacy; and 4). Information needs of different population groups and target audiences. This paper briefly surveys these four issues and discusses their implications for organizations who produce or report statistical information, and for broader educational efforts.

1. THE NATURE OF STATISTICS LITERACY

The term statistics (or statistical) literacy has not gained agreed-upon meaning. Wallman (1993) argued that statistical literacy is the ability to understand and critically evaluate statistical results that permeate daily life, coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions. Watson (1997) described three tiers of statistical literacy with increasing sophistication: basic understanding of probabilistic and statistical terminology; understanding of statistical language and concepts when they are embedded in the context of wider social discussion; and a questioning attitude one can assume when applying concepts to contradict claims made without proper statistical foundation. Gal (in press, 2002) argued that statistical literacy refers to two interrelated components, (a) people's ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena, and (b) when relevant, people's ability to discuss or communicate their reactions to such statistical information or messages.

Activation of statistics literacy may be called for in diverse contexts in which people encounter the much-heralded “information-laden” world, such as when people watch TV, read a

newspaper, visit Internet sites, or participate in community or political events. In such contexts statistical information may be communicated to the public, either directly by its producers (e.g., public agencies, research firms) or through reports in various media channels, in three ways—through written or oral text, numbers and symbols, and graphical or tabular displays; these three elements often appear in some combination and with varying degrees of sophistication.

The capabilities subsumed under "statistics literacy", and the processes involved in comprehending and reacting to statistical messages, are more complex than may seem. A model proposed by Gal (in press, 2002) assumes that people's statistical literacy involves both a *knowledge* component (comprised of five cognitive elements: literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions) and a *dispositional* component (comprised of two elements: critical stance, and beliefs and attitudes). As with people's overall numeracy (Gal, 2000), the components and elements in the proposed model should be viewed as a context-dependent, dynamic set of building blocks that together enable statistically literate behavior. In particular, understanding, interpretation, and reaction to statistical information require and depend *not only* on statistical knowledge per se, but *as much on* the availability of literacy skills, mathematical knowledge, and context-specific and general world knowledge. However, critical evaluation of statistical information (after it has been understood and interpreted) *also* depends on the abilities to access critical questions and to activate a critical stance, which in turn are supported by a set of beliefs and attitudes.

2. FACTORS AFFECTING THE DIFFICULTY OF STATISTICAL MESSAGES

The extent to which people can comprehend and react to statistical messages, or have difficulties in this regard, depend on the interaction of two groups of factors: (a) *task factors*, i.e., aspects of the text, numbers, and displays in the message, and (b) *person factors*, i.e., characteristics of the individuals engaged with a message. In this section we focus on task-related factors, which are usually under the control of producers and reports; a later section discusses person factors. It is argued that the difficulty of comprehending statistical messages depends on task demands related to *all* five knowledge areas listed above, i.e., literacy, statistical, mathematical, context, and critical questions. Due to space limits we provide illustrative points pertaining only to the first two of these five task aspects (see Gal, 2002).

Literacy aspects. All statistical messages involve text. People may have to decode and comprehend the meaning not only of prose or narrative text (written or oral), but also locate, navigate through, and interpret information in various tables, charts, or graphs. Hence, the complexity of statistical tasks is determined in part by literacy-related factors (Murray, Kirsch, & Jenkins, 1998). Readers have to comprehend surrounding text, i.e., within which the "pure" statistical portion is embedded or explained, to place the statistical part in the proper context. Text complexity is affected by the content and organization of a message's text, which are the result of work by the message originators (multi-disciplinary work groups, technical writers, officials, politicians, public relations personnel, journalists, etc.). Hence, readability and comprehensibility of messages depend on characteristics of their originators, who may have different writing or speaking styles, different levels of training in effective writing, and different aims and motives. Originators may use statistical terms and jargon sparingly or generously, and not necessarily accurately, for reasons such as their (possibly faulty) assumptions about knowledge or skill distributions within their audiences, desire to enhance the perceived scientific basis and the credibility of the message, or lack of sufficient statistical knowledge.

Multiple factors that affect the difficulty of comprehending both prose and non-prose components of text-based tasks were identified through empirical and conceptual work related to large-scale studies of adult literacy skills, such as the International Adult Literacy Survey (IALS; Murray, Kirsch, & Jenkins, 1998). Among other factors, task difficulty was found to be affected by the *plausibility of distracting text* or elements, by overall *structural complexity* (e.g., whether the document includes "combined lists" such as pie charts, "intersecting lists" such as two-way tables, or "nested lists" such as multi-element graphs), or by *document density* (e.g., the number of labels and text items that make up a list, table, or graph). Such text features affect the type of cognitive operations involved in making sense of prose and non-prose text elements. Tasks

become more difficult (Mosenthal & Kirsch, 1998) when text content and organization, and the situational demands, require increased use of *cycling* through parts of texts or displays, *integrating* information (e.g., across two graphs), *generating* new information (e.g., finding the difference between percentages in different parts of a table), or making *inferences*.

Statistical aspects. The complexity of statistical messages is obviously affected by their statistical (and mathematical) content. Obviously, understanding of the statistical aspects of statistical messages has to be founded on some familiarity or sensitivity, albeit an intuitive or rudimentary one, with "big ideas" in statistics, such as the omnipresence of variation and of random processes, or the need to reduce noisy data. Depending on the nature of the message and on the demands of the context in which a message is encountered, diverse knowledge pertaining to various statistical areas may be required to make full sense of messages:

- Knowing why data are needed and can be produced (e.g., to understand why an "experiment" was performed),
- Familiarity with basic terms and ideas related to descriptive statistics (e.g., to understand why a "median" is reported rather than a "mean"),
- Familiarity with basic terms and conventions about graphical displays (e.g., to be able to perform a literal reading of a graph, but also read "beyond the data" or identify misleading graphs or claims),
- Some understanding of basic notions of probability (.e.g., to understand information about side-effects),
- Knowing how statistical conclusions or inferences are reached (e.g., to understand why a reported difference is between groups "significant").

Overall, the characteristics of statistical message, including not only their literacy and statistical aspects illustrated above, but also aspects of the mathematical, world knowledge, and critical questions that were not examined here (see Gal, 2002), can affect the difficulty of a statistical message, apart from the characteristics of the person engaged with the task.

3. INDIVIDUAL OR GROUP DIFFERENCES IN STATISTICS LITERACY

As argued earlier, people's ability to comprehend statistical messages depends on the interaction between task-related factors, and characteristics of the individuals engaged with a message. Examples for relevant person-related factors are educational background, literacy skills, numeracy skills, world knowledge, as well as individual beliefs regarding mathematical or statistical issues, such as about the need for being critical towards information coming from public or media sources. The existing variability within the population in these and other person-related factors eventually contributes to individual and group differences in performance.

Several large-scale studies have examined skills subsumed in the model of statistical literacy proposed earlier. Results from the IALS (Statistics Canada and OECD, 1996) suggest that in most of the countries surveyed, adults vary a lot in terms of literacy and selected mathematical skills. A large proportion of adults have only basic text comprehension skills and are unable to cope effectively with a range of everyday tasks that demand more than locating textual information in the presence of distractors or basic inference. IALS has also shown that performance lacks on tasks specifically involving comprehension of information in graphs and tables, such as on tasks calling for cycling through displays to find specified information, or integrating information across displays.

Studies of school students also suggests that wide differences in knowledge bases related to statistical literacy exist in “would be” adults. Data from OECD's Programme for International Student Assessment (PISA), which assesses the extent to which students approaching the end of compulsory education (usually age 15) have the knowledge and skills needed for full participation in society, show wide variation within and across countries in terms of reading, mathematical, and scientific literacies (OECD, 2001). Using data from the Third International Mathematics and Science Study (TIMSS), Mullis, Martin, Beaton, Gonzalez, Kelly, and Smith (1998) examined how well students in their *final* year of schooling (usually grade 12) can detect a discrepancy between displayed data and a given interpretation of these data, one of the most basic skills educators usually use as an example for a statistical literacy skill expected of all citizens. Students

were asked to explain whether a reporter's statement about a "huge increase" was a reasonable interpretation of a bar graph showing the number of robberies in two years; the graph was manipulated so that a small difference between years will appear large. On average, *less than half* of all *graduating* students performed well on this task. Keeping in mind that in many countries a sizable proportion of students leave *before* the final year of high school, the overall percentage of all school leavers who can cope with such tasks should be even lower.

The skills examined by IALS, PISA, TIMSS, and related studies by no means cover all the knowledge bases that underlie people's statistical literacy. Little comparative information exists regarding adults' overall numeracy skills, and especially regarding understanding of basic statistical concepts that often appear in the official reports or in media articles, such as average, median, sample, margin of error, significant difference, understanding of chance-related statements, and so forth. Only a small percentage of adults have had any formal education in statistic, and in many countries a majority of students are still leaving schools with only rudimentary exposure to statistics (Moore & Cobb, 2000). Overall, wide differences have been documented, and others are likely to exist within the adult population in many countries in terms of the statistical literacy skills of the population. This implies that different population groups may require different types of communicative products, or otherwise should become the target of educational efforts aimed at developing their statistical literacy skills.

4. INFORMATION NEEDS OF DIFFERENT TARGET AUDIENCES.

National statistics offices are one of the key sources of statistical data and information in any country. Originally created to serve the narrow interests of governments, national statistical offices are now expected to provide a wide range of products and services to a broad spectrum of users, described below. These users differ greatly in their information needs and, more importantly for this paper, in their ability to understand and absorb statistical information. Hence, lessons learned by these institutions may be valuable for a range of other organizations which produce or report statistical information, and can inform a broad understanding of the role of different producers and reporters in addressing statistical literacy needs.

The general public. The general public requires statistical information to support their various life roles as citizens, workers, consumers, or community members. The public can be segmented into several subgroups which may have unique needs for information on specific topics. For example, a significant fraction of the general public are parents, and require statistical information to assist them in making myriad decisions about their children's health and wellbeing. Education is a key vehicle for knowledge transfer and a key mediating force in the determination of economic and social success. Naturally, parents are interested in understanding how the education system is serving their children or what impact it will have on children's future lives. Hence, parents need access to specific and often highly concise and friendly information about issues such as educational outcomes in different schools or areas, factors that influence children's development and learning, or dangers in the family's social or physical environment, such as on health or crime issues.

Similar descriptions of specific information needs can be generated with regard to other population groups, such as the elderly, who may have concerns about, e.g., personal financial planning, the state of the social security system, or long-term impact of medical, lifestyle, and nutritional choices. "Parents" and "elderly" are examples of generic labels for heterogeneous groups characterized by diversity in formal education and in the various knowledge-bases required for statistical literacy, such as in literacy, numeracy, or formal statistical knowledge. Such diversity is due in part to changes in educational systems or in immigration patterns.

Statistical information reported by various producers is crucial to parents, elderly, and many other groups from all walks of life on trends or changes in social, economic, environmental, and other conditions, and on the efficiency and effectiveness of public institutions and various service providers; statistical information can assist people in judging or risk and promise of various courses of action, and can help them in deciding where and how to invest limited resources. Yet, needs assessments conducted by Statistics Canada suggest that citizens do not wish to read detailed published material themselves; they are generally content to rely on

secondary sources such as the media to provide them with the information they require, and in most cases need only highly abstracted or encapsulated information. Few citizens are capable of undertaking primary data analysis themselves, but with the improvement in educational outcomes and the public's sophistication, a growing fraction are able and interested in having access to more detailed information such as data tables that relate to their own locality or circumstances.

Policy makers, senior officials, and politicians. These users are in general responsible for making public policy and decisions on expenditures from the public purse on behalf of constituents. In theory this group requires objective information to reach optimal decisions about public investments. In reality, however, they sometimes employ information to rationalize rather than inform decisions, and may be as much influenced by what they have personally read or heard in the media than by specific elaborate analyses and reports prepared on their behalf. This reinforces the role that official statistics play in providing a rhetorical structure and commonly held fact base upon which productive public discourse rests.

Because they control the content and timing of much new data collections, this group can exert a profound influence over the content of national and local statistical systems. At the same time, as a target audience for statistical reports, this group is quite heterogeneous. Some policy makers and officials may have advanced training or experience in critical reading of research reports, but as MacCoun (1998) argues, basic training in research methods is no guarantee against biases or difficulties in interpreting results. Other policy makers and politicians may have only moderate or no training in statistics or in interpreting complex data patterns, and have to resort to relying on highly abstracted information or executive summaries produced for them.

Administrators and advocacy groups. These users require statistical information to manage their affairs at both the strategic and tactical levels, and need data at the finest level of detail available to inform "local" choices. For example, businesses require aggregate information on the state of the overall economy but as much on their own industry or region. Managers of educational and human service institutions require information on demographic trends, participation rates, changes in labour market skills demands, or unemployment trends in *specific* sectors or regions, to inform their program offerings. Organizations with an advocacy role may require statistics that pertain to their specific stakeholders, such as social, economic, or health indicators of interest to parents, elderly, community coalitions, or citizens in specific regions.

It follows that administrators and decision-makers in local or cause-oriented organizations have quite similar needs to those of national policy-makers and politicians, but on a different level of specificity. Nonetheless, members in this group (which also include, e.g., volunteers on steering committees of community organizations or directors on educational boards) may lack the technical and financial resources to take full advantage of primary data offered by national statistical agencies; also, they do not necessarily have the statistical sophistication or supportive consultancy needed to interpret detailed reports. Hence, many members in this group may have to rely on summary products geared for their characteristics and needs, or otherwise a way to extract more "local" information from large-scale primary sources.

The media. The media plays a key role in transforming the output of national statistical systems or other research bodies into digestible chunks, alerting readers/viewers to the importance of particular facts and highlighting their implications for individuals and for public policy. However, given the media's need to publish news that generate readers' interest and that increase viewership and sales, media organizations and individual reporters face conflicts of interest and do not always keep to balanced and accurate reporting (Crossen, 1994). Further, many journalists are bombarded with information by various parties interested in advancing specific political or financial causes (Franklin, 1999) and do not necessarily have the statistical knowhow or time needed to critically analyze complex research reports. Thus, reporters may have to rely on others to provide them with reliable interpretations of formal reports and support their ability to effectively communicate to their audiences technical issues or complex patterns of statistical findings in a comprehensible and friendly yet also accurate way.

Researchers. Researchers in academic and other contexts play a central role in designing statistical enquiries and in transforming resulting data into information for other users, employing

the tools and techniques of science to ensure that what is observed can be safely generalized. That said, the research community is heterogeneous with respect to research skills, statistical training, and statistical literacy. Researchers also have diverse information needs, and many researchers require only access to published reports. A second group of researchers requires access to published reports and need to be able to specify tailored outputs for their private use. Finally, a third group of researchers requires access to the primary data at the micro level (e.g., individual records) in order to extract the maximum amount of statistical information, and can be thought of as users as well as producers of statistical information.

5. DISCUSSION AND IMPLICATIONS

The use of official and other statistics is growing rapidly and is serving an important array of different users. Users of the information collected and distributed by large research organizations differ greatly both in their ability to extract information from the underlying data and to interpret the meaning of empirical evidence or reported findings, as well as in their information needs. Based on the discussions above, we examine below three areas of particular relevance to statistics education.

A range of products. Viewed from a marketing management perspective, to achieve the maximum return on their (and the public's) investment, research organizations need to plan, develop, and align their products and services to the needs and expectations of key user groups, and match the content and attributes of products to the statistical literacy and related competencies of users groups. In practical terms, this translates into the publication of multiple variants based on the same broad analyses, making sure that publications incorporate multiple rhetorical levels and devices and organized so as to respond to the questions and concerns that user groups may have. The above poses challenges for producers of statistical information, as an increasing share of organizational resources must be devoted to profiling the needs and capability of different user groups, and reports and displays must be created to be highly abstracted yet also proof against misinterpretation by naive users.

Traditionally, the requirement for producers of any type of print-based information to the public, such as in the context of creating patient education leaflets, has been to make sure that texts are written at an appropriate readability level; the readability of documents has often been assessed (at least in English) by readability formulas. However, the expectation presented here refers to matching products to the *statistical* literacy of their target audiences. This requires going far beyond the use of readability formulas which have many limitations, or the emphasis on stylistic and technical aspects of "good writing", such as that texts are well organized, attractive, avoid complex language, or use fonts that are large enough (Duffy & Waller, 1985).

In developing statistical products for different user groups, there is a need to consider that (a) five types of underlying knowledge and skills *jointly* impact the comprehension of statistical messages, and that (b) many user groups not only have a limited range of literacy and comprehension skills, but also partial or little familiarity with technical terms, big ideas, or critical questions in statistics. Data from existing or planned large scale studies, such as the IEA's Third Mathematics and Science study (TIMSS), the OECD's Program for International Student Assessment (PISA), or from Statistics Canada and NCES's upcoming Adult Literacy and Lifeskills Survey (ALL), provide a means to profile some basic aspects of the receptive capacity of broad groups in the population. However, more information is needed in this regard on the many skills and types of knowledge that are not assessed by such studies.

Statistics educators can support and inform the actions of producers of statistical reports, through collaborating on studies of the skills and needs of members of different user groups, or through sharing the implications of lessons they have learned from teaching statistics to different types of learners. We refer here broadly not only to those who teach formal statistics in regular education systems such as in diverse schools and academic institutions, but just as much to experiences gained with various types of adult learners, such as in adult education classes or in workplace training and skill upgrading programs, where statistical topics may sometimes be subsumed under broader rubrics of numeracy, literacy, or basic skills education. At the same time, the expectation that eventually many statistical investigations have to be summarized in

ways that suit the information needs and skills of different types of audiences should impact the curriculum and classroom assignments of students in statistics classes, as part of preparing them to apply their skills in the real world.

Sensitivity to interpretive issues. The demand that a range of reports at different levels of specificity is prepared for different users raises serious challenges for research organizations, and by implications for those interested in statistics education. It becomes critical that systems be put in place to document information even for users who are not necessarily sophisticated, who may comprise the majority of the general public and other user groups. Users should be able to find out (in a report, in a related product, on an Internet site) what is being analyzed, why it is being analyzed, how it is being analyzed, what is the underlying conceptual framework, the fitness of the study to inform various uses, what inferences can safely be drawn from the analyses, what social, economic, or other import the analyses hold, and what are the limitations imposed by the data-gathering process on the quality of the data and on the possible conclusions.

"Value added" analytic products require making specific choices about what data or patterns to show, what findings to interpret, what implications to discuss, but also what to bypass, ignore, or downplay. The need to tailor analyses for different user groups brings increased risks associated with the fact that it is difficult, if not impossible, to present findings in a neutral way. Invariably statisticians and authors make judgements, either implicit or explicit, that reflect their own value structures and priorities. Given that the majority of users are operating on the basis of trust, any product of questionable quality risks putting the entire output of the agency at risk, especially when the underlying conceptual framework or the collected data are weak, flawed or the subject of public and/or academic debate.

Eventually, the need to respond to the information needs of different groups by preparing abstracted reports risks politicizing the basic collection and dissemination functions of research organizations, and places huge pressure on the processes put in place to assure quality at all stages of the analytic and production processes. For statistics educators, the types of challenges facing statistical organizations trying to fulfill their public and organizational missions have to inform what transpires in the classroom, and be reflected in the curriculum. Students, in their current or future roles as citizens, as members of a key user group, or as participants in research projects (e.g., as employees), have to become sensitive to the inevitable value-laden and sometimes political nature of the decisions made by (or for...) research organizations regarding what and how to research, what and how to report, and to whom.

Research organizations as statistics educators. The above discussion leads to the inevitable conclusion that research organizations can and in many cases have to assume a broader and more involved role than just seeing themselves as responsible only for collection and dissemination of credible data and findings. Research organizations have to fulfill educational functions, and proactively plan "client education" processes, to increase the chance that their diverse users can extract maximum value from the reports and information products offered to them. Client education can take many forms, such as stand-alone activities (workshops, educational booklets for specific user groups, "guided tour of statistics" components on an internet site), or as elements embedded in core products, such as adding explanatory comments, glossaries, or sidebars that provide additional explanations in context. Obviously, the value added by such devices should be empirically studied in order to evaluate its effectiveness.

In the longer term, statistical agencies must look to the needs of future cohorts of users. It would appear from the profiles of literacy and numeracy skills flowing out of international comparative assessments such as TIMSS, PISA, or ALL, that the statistical needs and statistical literacy of today's students far exceed those of previous generations. Armed with the Internet, these users will come to expect instant access to well organized and clear information that is also free information. In such an environment national statistics offices and other research organizations are only one of many possible providers of statistical information. As mentioned earlier, the media works to package and report information as well. Hence, research organizations will have to devote resources to creating brand awareness and perceived quality in order to increase the chance that citizens and decisions makers at various levels will choose to access and rely on their official data and reports rather than on other sources or on anecdotal information

(Wanta, 1997). Statistics Canada's educational outreach program is motivated in part by these educational and marketing concerns; this program delivers statistical information and curricular resources to elementary and secondary teachers and their students over the Internet. Thus, new types and challenges will await statistics educators, once learning and skill improvement by different groups or the general public transcend the walls of traditional classrooms and extend to a broader network of information sources.

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