# STATISTICAL LITERACY REQUIREMENTS FOR TEACHERS

Jeffrey Hovermill, Brian Beaudrie, and Barbara Boschmans
Department of Mathematics and Statistics, Northern Arizona University, Flagstaff, AZ, USA
Jeff.Hovermill@nau.edu

*This paper examines the relationship between statistical literacy in a broad sense and international teacher preparation and student learning standards pertaining to statistics. This paper begins with a discussion of why statistical literacy is essential in today's society and the consequences, on an individual and societal level, of not being statistically literate. Since teachers should play a primary role in developing statistical literacy, the authors present an examination of teacher preparation and student learning guidelines from multiple countries in the area of statistics. The authors present conclusions regarding the alignment between societal statistical literacy requirements and teaching and learning guidelines. Recommendations for meeting teacher statistical literacy requirements are offered based in this analysis.*

## INTRODUCTION TO STATISTICAL LITERACY

> "…and the time may not be very remote when it will be understood that for complete initiation as an efficient citizen..., it is as necessary to be able to compute, to think in averages and maxima and minima, as it is now to be able to read and write." – H. G. Wells, *Mankind in the Making*, 1903.

During the last several decades, the importance of developing a statistically literate citizenship has gained momentum. This need has accelerated primarily because the world has become increasingly dependent upon statistical data. With the communications technologies available to most of the modernized world, citizens in these societies obtain instantaneous access to statistical information via radio, television, the World Wide Web, and so on. Claims by politicians, pundits, and advertisers that are statistical in nature are part of life in today's modern society. A statistically literate citizen would be able to understand this information, and be able to make responsible decisions based on this information.

The literature contains several definitions of statistical literacy. The following definitions of statistical literacy were aggregated by Rumsey (2002):

- People's ability to interpret and critically evaluate statistical information and data-based arguments appearing in diverse media channels, and their ability to discuss their opinions regarding such statistical information. *Iddo Gal, University of Haifa*
- The understanding of statistical language: words, symbols, and terms. Being able to interpret graphs and tables. Being able to read and make sense of statistics in the news, media, polls, etc. *Joan Garfield, University of Minnesota*
- ... the ability to understand statistical concepts and reason at the most basic level. *J. Laurie Snell, Dartmouth College*
- ... comprehend text and the meaning and implications of the statistical information in it, in the context of the topic to which (it) pertains. *Jane Watson, University of Tasmania*

Milo Shield, the director of the W. M. Keck Statistical Literacy Project based out of Augsburg College in Minnesota, provides yet another definition. According to Shield (1999), "Statistical literacy is the ability to read and interpret data: the ability to use statistics as evidence in arguments. Statistical literacy is a competency: the ability to think critically about statistics." A final definition, credited to the United Nations Development Dictionary and found on StatLit.org (2013), states statistical literacy is "the ability to read and interpret statistics, and think critically about arguments that use statistics as evidence."

An interesting facet emerges when reading these definitions: the words *calculate, solve,* or *compute* never appear in them. Instead, the definitions are dominated by the words *interpret, read, understand, think*. Statistical literacy concerns understanding statistics in their context; what they are telling us, or perhaps more importantly, what they are not. It is not about the calculations that

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seemingly dominate much of statistics education in the schools, such as making various kinds of graphs, finding measures of central tendency, calculating standard deviations and so on; it is about understanding what these measures tell us in the context of the situation.

An analogy between statistics and statistics literacy could be made using language literacy. Consider the sentence 'the elephant walked through the jungle.' It would be possible to teach someone to read this sentence phonetically in English, and pronounce all of the words and syllables correctly, without this hypothetical person ever knowing what he or she was saying…for example, they have no idea what an elephant is, or what a jungle might look like. Performing the mechanics of speech - saying the sentence - is analogous to performing the calculations involved in statistics. Knowing the meaning of the words is, of course, literacy. Statistics literacy goes beyond the calculations involved, and is the understanding the statistics and the context in which they are found.

Continuing with the ideas of literacy, if a person was illiterate, he or she would be at a serious disadvantage in today's modern society. A parallel can be drawn to those who are statistically illiterate. For example, in the U.K. the newspaper *The Telegraph* reports that statistical illiteracy "…has left large swathes of the British population virtually incapable of seeing through what politicians, officials, and even salesman tell them…" (Bingham, 2012). In John Allen Paulos' 1988 book *Innumeracy: Mathematical Illiteracy and its Consequences*, he discusses how a person's (or a societies') lack of understanding of the probabilities of risk (such as dying in an airplane crash or from a terrorist attack) can lead to "unfounded and crippling anxieties or to impossible and economically paralyzing demands for risk-free guarantees." (Paulos, 1988, p. 4). As Best (2008, p. 127-128) states, "such statistics are intended, not just to inform people, but to shape their attitudes and behaviors." A lack of statistical literacy could be costly, both at an individual level and at a societal level. By contrast, someone who is comfortable with statistics and understands their meaning will enjoy many benefits. Therefore creating individuals and societies that are statistically literate would be advantageous to those individuals and that society.

## STATISTICAL LITERACY LEARNING STANDARDS

Standards for learners of statistics from more than two dozen countries on six continents were examined for this report. Guiding documents from several countries (e.g. United States' Common Core State Standards for Mathematics, South Africa's Outcomes and Assessment Standards for Mathematics, and China's Mathematics Curriculum Standards) were found to include language that corresponds with definitions of statistical literacy. Examples were purposely selected from across multiple grades and countries that, if met, provide opportunity for students to embody the goal of statistical literacy are reported below in Table 1.

Table 1. Examples of statistical literacy learning goals by country and grade level

| | | |
|---|---|---|
| Year 3 | Australia | Students know that some questions and issues, including statements and questions they have created themselves, can best be answered by collecting data. They work out suitable ways to do this, including the use of technology to access existing data, and explore the best ways of organizing it. They present the data in ways that assist its interpretation. They make simple statements, including predictions about likelihood, what is possible and what is not, whether variation exists within the set of data or with existing data, and decide whether additional data should be collected. |
| Year 5 | Finland | The pupils will know how to gather data and organize, classify, and present them as statistics. |
| Year 7 | New Zealand | In contexts that require them to solve problems or model situations, students will be able to investigate summary, comparison, and relationship questions by using the statistical enquiry cycle:<br>- gather or access multivariate category and measurement data<br>- sort data and display it in multiple ways, identifying patterns and variations<br>- interpret results in context, accepting that samples vary and have no effect on one another |

| | | |
|---|---|---|
| Grade 9 | South Africa | The learner will pose questions relating to human rights, social, economic, environmental and political issues in South Africa; select, justify and use appropriate methods for collecting data (alone and/or as a member of a group or team) which include questionnaires and interviews, experiments, and sources such as books, magazines and the Internet in order to answer questions and thereby draw conclusions and make predictions about the environment; organize numerical data in different ways in order to summarize by determining: measures of central tendency; measures of dispersion; draw a variety of graphs by hand/technology to display and interpret data including: bar graphs and double bar graphs; histograms with given and own intervals; pie charts; line and broken-line graphs; scatter plots; and critically read and interpret data with awareness of sources of error and manipulation to draw conclusions and make predictions about: social, environmental and political issues (e.g. crime, national expenditure, conservation, HIV/AIDS); characteristics of target groups (e.g. age, gender, race, socio-economic groups); attitudes or opinions of people on issues (e.g. smoking, tourism, sport); any other human rights and inclusivity issues. |
| Secondary | Argentina | Interpret the meaning of the central parameters (mean, median and mode) and analyze its limits to describe the situation under review and for making inferences and arguments for decision-making. |

While the list in the table above is not comprehensive – in other words, not every countries' guiding documents were able to be examined, nor were we able to include all countries standards that contained statistical literacy ideas – it is easy to see that for several countries, in many different grade levels, aspects of statistical literacy exists in their standards. Statistics educators from some counties we communicated with, by contrast, feel that the learner standards from their home countries have a long way to go to shift towards more focus on statistical literacy and less on calculation. Whatever country readers of this paper are from, we hope that the examples above provide valuable opportunities for grounded discussions about what learners of statistics can be expected to think about and do at what grades as they develop statistical literacy. The next question we examine is whether learners are meeting these robust standards?

## ASSESSING STATISTICAL LITERACY

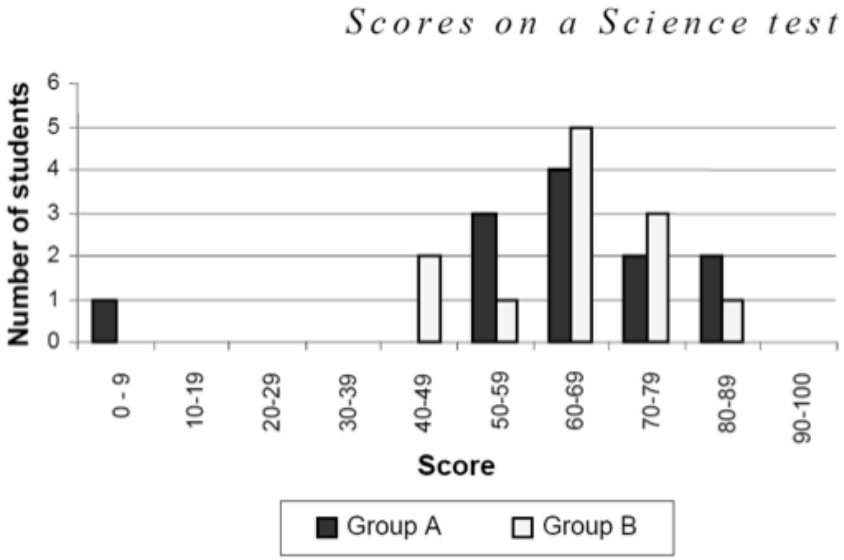
The Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) are international studies that aim to evaluate education systems worldwide by testing the skills and knowledge of students. The PISA Uncertainty and Data mathematics content category aligns with statistical literacy expectations and includes "recognizing the place of variation in processes, having a sense of the quantification of that variation, acknowledging uncertainty and error in measurement, and knowing about chance" as well as "recognizing the forming, interpreting and evaluating conclusions drawn in situations where uncertainty is central" (OECD, 2013). An example of a 2003 PISA assessment item, 'Scores on a Science Test', measuring statistical literacy is included in Figure 1, below. Based on the evidence of the results from this item in 2003 when only 33% of students from 34 participating countries were able to correctly give at least one valid argument in support of Group A, it appears there was much room for growth in statistical literacy among 15 year old students.

Many of the TIMSS released assessment items were more procedural in nature than those in PISA, in our opinion, however some items did align with the vocabulary used to describe statistical literacy and may serve as a measure of how well these learning goals are more recently being met. Since PISA had not released Uncertainty and Data results since 2003, we examined a 2011 8$^{th}$ grade TIMSS Data and Chance problem, shown in Figure 2.

Unfortunately, on the TIMSS item in Figure 2, the international average percent of correct responses among 8$^{th}$ grade students from 42 participating countries was only 13% (TIMSS, 2011). This problem continues to exemplify that not all statistical literacy goals are being met. Furthermore, standardized assessment items cannot measure broader statistical literacy goals related to developing citizens who regularly apply their understanding to their lives. The next section focuses on what teachers and teacher educators in some countries are doing to help continue progress towards meeting statistical literacy goals.

The diagram below shows the results on a Science test for two groups, labeled as Group A and Group B.

The mean score for Group A is 62.0 and the mean for Group B is 64.5. Students pass this test when their score is 50 or above.




Looking at the diagram, the teacher claims that Group B did better than Group A in this test.

The students in Group A don't agree with their teacher. They try to convince the teacher that Group B may not necessarily have done better.

Figure 1. Example PISA statistical literacy assessment item

The Real Burger Company owns 5 restaurants. The numbers of staff members employed in its 5 restaurants are: 12, 18, 19, 21, and 30 people.

C. If the restaurant with 30 staff members increased its number of staff members to 50, how would this affect the median and the mean?

Figure 2. Example TIMSS statistical literacy assessment item.

## TEACHING FOR STATISTICAL LITERACY

Embedded in the Statistical Literacy Standards for Learners, two countries added content specific notes for teachers. Other countries added general teaching strategies and focused on mathematical practices for learners to become good problem solvers, but these two countries stood out for including the notes to teachers within their learner standards. See Table 2, for examples.

The kinds of detailed guidance included by China and Brazil in their standards documents seems valuable towards supporting teachers in focusing on 'the big picture' of statistical inquiry while planning and facilitating teaching and learning.

Many other countries have described teacher education initiatives that aim to support schools and teachers in focusing on and developing a deeper understanding of the role of data and chance in statistics education (Moore, 1990). Initiatives that immerse teachers as learners, first, are essential if we expect teachers to be able to effectively develop statistical literacy in their students. Most mathematics teachers have not learned statistics deeply even if they have taken previous formal statistics coursework and are often not prepared to enthusiastically (Stohl, 2005) and/or instructionally develop key ideas 'from the ground up' by asking questions of and investigating meaningful data with their students (D'Amelio, 2010).

Table 2. Notes to Teachers about Teaching Statistical Literacy

| | | |
|---|---|---|
| Note to Elementary Teachers | Brazil | It is an increasingly frequent need to understand the information conveyed, especially by the media, to make decisions and predictions that will influence not only personal life, but also the whole community. This feature of contemporary life brings to the mathematics curriculum demand to address elements of statistics, combinatorics and probability. Primary grade activities may be related to issues of interest to the child; for example, working with birth dates, weight, height, nationality of grandparents, preferred football teams, etc. can be organized and presented graphically. In the construction of graphs it is important to check if students can read the information represented in them. Students should be asked to give their interpretation of graphs and to think of questions that can be answered from them. |
| Notes to Secondary Teachers | China | Statistics seek to extract information from data. During teaching, teachers should pay attention to the intimate relationships between contents of learning and realistic everyday living. Attention should be paid to enable students to experience consciously simple statistical data processing, make simple judgment and prediction in the light of data, and engage in exchange of ideas. Experiences on possibilities in concrete situations should not be neglected. Teachers should guide students to choose different methods so as to obtain appropriate samples in accordance with the practical problem requirements, and to extract number characteristics from the sample data. Teachers should not treat statistics as number crunching and graph plotting. Regarding concepts in statistics (e.g. population, sample), there is a need to integrate these with concrete problems for descriptive explication. Teachers should not quest for rigorous formal definitions of these concepts. There is a need to avoid students carrying out sheer calculation of statistics. |

North, Scheiber, and Ottaviani (2010), highlighted a successful program to ‘upgrade the statistics knowledge of teachers’ during ICOTS 8. They incorporated data that was meaningful to participating South African teachers and provided strong training and support while developing a trainer of trainers model. Franklin and Kader (2010) outlined the importance of focusing teacher education on developing teacher understanding of statistical literacy, thinking, and reasoning while also supporting their ability to prepare to facilitate a cohesive and coherent curriculum to their students.

Statistics education is growing in recognition and importance all over the world (UNESCO, 2013). “The importance of developing the statistical literacy of our future generations is critical...to develop critical thinkers and capable consumers of information that would ultimately benefit social progress.” “This group includes school students as the next cohort of 'data generators' and 'data users' and also school teachers as the necessary facilitators for this outcome” (UNECE, 2012, p. 9).

It is evident that in order to meet this demand we must continue to develop statistical literacy in teachers. As we work to meet this call we would be well served to remember seven principles of effective professional development (Loucks-Horsley, 2010): hold a clear, well-defined image of effective classroom learning and teaching; provide teachers with opportunities to develop content knowledge and pedagogical skills; use instructional methods which mirror the methods to be used with students; build or strengthen the learning community of teachers; prepare and support teachers to serve in leadership roles; provide links to other parts of the educational system; and include continuous assessment.

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