STATISTICS: A LOOK ACROSS K-8 STATE STANDARDS

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This analysis of the K-8 statistics standards in 41 United States of America (USA) state documents that include grade level expectations (GLEs) is timely given the increased need for statistical literacy as the quantity of available data around us grows. This analysis endeavors to answer the question: What are K-8 students in the USA expected to know and be able to do with regard to statistics as represented in the state standards documents? The study was framed using the four process components outlined in the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report: (1) formulate questions, (2) collect data, (3) analyze data, and (4) interpret results (Franklin et al., 2007). Among other findings, the analysis highlights two major types of knowledge expected in the documents, the knowledge expected to "do" each of the four processes and the knowledge expected to "understand" and/or "evaluate" the processes.

INTRODUCTION

> Our lives are governed by numbers. Every high school graduate should be able to use sound statistical reasoning to intelligently cope with the requirements of citizenship, employment, and family and to be prepared for a healthy, happy, and productive life. (Franklin et al., 2007, p.1).

Shaughnessy (2007) outlines evidence of the increasing emphasis on statistics education in the United States of America (USA), crediting the National Council of Teachers of Mathematics (NCTM) for its contribution in the early stages of this movement. NCTM, in its "groundbreaking" document *Curriculum and Evaluation Standards for School Mathematics* (1989), "placed statistics on an equal footing with number sense, algebra, geometry, and measurement as a critical foundation stone for school mathematics" (p. 957). Shaughnessy provides several sources of evidence of the increasing prominence of statistics in the mathematics curriculum in the USA: (1) the "boom" of research and curriculum development projects addressing statistics, (2) the increasing number of conferences devoted to statistics education, (3) the unprecedented growth of enrollment in AP Statistics in USA high schools (growing at a faster rate than any course in the history of the Advanced Placement program), and (4) the takeover of calculus by an 'introductory statistics' course for the largest enrollment in any mathematics or statistics class at many USA colleges and universities.

In spite of this promising news regarding students' current and growing exposure to statistics topics, Shaughnessy expresses several areas of concern. First, does this exposure to statistics include primarily procedures such as calculating mean and constructing graphs and tables or a higher level of statistical literacy in which students are able to make decisions about the most appropriate statistical representations (including numerical and graphical) and become competent consumers of statistical information encountered in everyday experiences? Second, are students receiving statistics education throughout their K-12 mathematics program? And finally, are teachers prepared for the challenge of engaging students in statistics in meaningful ways? These questions are echoes of similar concerns expressed earlier (e.g., Burrill & Camden, 2005; Groth & Bergner, 2005; Utts, 2003).

Historically, education in the USA has largely been controlled at the state and district level. This is in sharp contrast to most countries in which education is managed primarily at the national level. However, the passage of the federal No Child Left Behind Act (NCLB, 2001), which requires that states adopt "challenging academic content standards" in mathematics, reading/language arts, and science for all children in all schools and measure the achievement of students in grades 3 through 8 against these standards, marked a shift in the existing system of state and local control. Although the standards and assessments were to be created at the state

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level, failure to make "adequate yearly progress" (AYP) toward "continuous and substantial academic improvement" for all students would result in the state's loss of federal funds. Therefore, the standards and assessments thereof have become extremely important documents in schools, often serving as curriculum.

The new attention to these documents is evidenced by the fact that between 2002 and 2006, 39 states (the District of Columbia and the Department of Defense Education Activity are counted as states for the purposes of this analysis) published new mathematics curriculum standards (Reys, 2006). It is at the intersection of these two phenomena, the increasing emphasis on statistics education in the USA mathematics curriculum and the growing attention being paid to state mathematics standards, that this study is situated. It seeks to address the first of Shaughnessy's (and others') concerns regarding the quality and quantity of statistics education in the K-8 USA mathematics curriculum. That is, according to the state standards what are K-8 students expected to know and be able to do with regard to statistics? The analysis was framed using *Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report* published in 2007 by the American Statistical Association (ASA). The *GAISE Report* proposed four process components of the statistical investigative process: (1) formulate questions, (2) collect data, (3) analyze data, and (4) interpret results (Franklin, et al., 2007). This study used these process components to examine the statistics curriculum in state standards documents. Given the concerns expressed in the literature regarding the procedural nature of current statistics education, we expected to find this type of expectation in the state standards documents. However, we were also hopeful that we would find expectations that went beyond the procedures into decision-making about the most appropriate statistical representations and producing competent consumers of statistical information.

METHOD

We collected all of the statistics grade level expectations (GLEs) from 41 state standards documents and coded each GLE into the applicable process components (i.e., Formulate Questions, Collect Data, Analyze Data, and Interpret Results) using the descriptors provided in the *GAISE Report* (Franklin et al., 2007, p. 11):

1. Formulate Questions: i) clarify the problem at hand; ii) formulate one (or more) questions that can be answered with data;
2. Collect Data: i) design a plan to collect appropriate data; ii) employ the plan to collect the data;
3. Analyze Data: i) select appropriate graphical and numerical methods; ii) use these methods to analyze the data;
4. Interpret Results: i) interpret the analysis; ii) relate the interpretation to the original question.

Many GLEs were coded into more than one process component. Table 1 provides several examples of GLEs and the way they were coded in our analysis using these descriptors from the *GAISE Report*.

Table 1. Sample GLEs with their coding

Sample GLE	Formulate Questions	Collect Data	Analyze Data	Interpret Results
Construct and interpret broken line graphs, line plots, bar graphs, picture graphs, glyphs and simple circle graphs. (Connecticut, grade 4)			x	x
Gather data and use information to complete a scaled and labeled graph. (South Dakota, grade 3)		x	x	
Pose information questions; collect data; and record the results using objects, pictures, and picture graphs. (California, Kindergarten)	x	x	x	

We noted very quickly that within each process there were two distinctly different types of GLEs. Type I GLEs, as they will be called here, expect students to "do" the process, and Type II GLEs expect students to understand and/or evaluate the process. Table 1 above provides examples of Type I GLEs. For example, California expects that students in Kindergarten will pose questions, collect data, and record the results using objects, pictures, and picture graphs. In this example, students are expected to "do" the following processes: Formulate Questions, Collect Data, and Analyze Data. Table 2 provides sample GLEs to illustrate Type II expectations.

Table 2. Samples of Type II GLEs

Sample GLE	Formulate Questions	Collect Data	Analyze Data	Interpret Results
Recognize practices of collecting and displaying data that may bias the presentation or analysis. (Michigan, grade 8)		x	x	
Formulate a question and collect data from a population, describing how the questions, collection method, and sample population affect the results. (Washington, grade 7)	x	x		
Recognize and analyze faulty interpretation or representation of data. (Maryland, grade 7)			x	x

Here, seventh graders in Maryland are not expected to represent and interpret data, rather they are expected to discern when data is misleading. GLEs can be considered both Type I and Type II. The second sample GLE in Table 2 provides such a case. The beginning of the GLE addresses processes typical of Type I (e.g., formulate a question) while the second part (e.g., describing how various parts of the process affect the results) is typical of a Type II expectation.

The next sections of the paper will be devoted to our findings. We will begin with an overview that describes the big picture in K-8 statistics as represented by 41 state standards documents, followed by sections devoted to each of the four processes: (1) Formulate Questions, (2) Collect Data, (3) Analyze Data, and (4) Interpret Results. Based on the findings from the analysis, the paper concludes with recommendations for preparing teachers to implement the statistics curricula present in the state standards documents for K-8 students.

RESULTS AND DISCUSSION

General Findings

In the 41 state standards documents, there were 1,711 GLEs that addressed at least one of the four process components described earlier. In total across the 41 states, the number of GLEs increases steadily from Kindergarten (98 GLEs) until grade 7 (244 GLEs) and then decreases slightly in grade 8. Nearly all of the 41 states analyzed have statistics GLEs at every grade level. The number of GLEs coded into each of the four process components, Formulate Questions, Collect Data, Analyze Data, and Interpret Results were 112, 423, 968, and 867 respectively. In subsequent sections, we provide a more in-depth look at the four processes.

Formulate Questions

The *GAISE Report* (2007) elaborates "Formulate Questions" as recognizing and understanding the situation or problem that is to be studied and formulating questions that can be answered by collecting, analyzing, and interpreting data. With this in mind, we included those GLEs that contain an expectation for the student to formulate a question or to identify the general purpose of the statistical investigation. Only 112 GLEs (about 7%) of 1,711 Statistics GLEs expect students to formulate questions for investigation. These GLEs represent 29 of the 41 states in the analysis. Overall, GLEs in this process span Kindergarten through grade 8, with

a concentration in grades 2, 3, and 7. Florida includes the greatest number of GLEs in this process component (11 GLEs).

An examination of the 112 GLEs in this process revealed essentially two different categories of expectations: those that expect students to formulate a question to launch an investigation (Launch GLEs) and those that expect students to formulate a question for a survey to collect data (Tool Question GLEs). Of the 112 Formulate Question GLEs, 67% (representing 27 states) were classified as Launch GLEs. All of these GLEs are Type I, in that they expect students to complete a task. While most Launch GLEs use a question to start a statistical investigation, 27% expect students to formulate a question at the end of a statistical investigation in order to start a new investigation. This subgroup of Launch GLEs, referred to as Relaunch GLEs, only appears in grades 4 through 8 and is expected by only seven states.

Eleven states include GLEs that expect students to formulate questions for the purpose of data collection. We categorized 39 GLEs out of the 112 Formulate Question GLEs (35%) as Tool Question GLEs; the maximum number of GLEs in this category occurred in Florida and Arizona with 10 and 9 GLEs respectively. Some of the Tool Question GLEs require students to recognize whether a question is appropriate or to understand how the tool questions affect the collected data. These GLEs (13 in total), referred to as Type II Tool Question GLEs, were found in five states. The majority of the focus on writing questions for data collection (Type I) exists in grades 1 through 4, while the Type II focus generally increases to grade 7.

Collect Data

Data collection, the second component of the statistical process involves many decisions and strategies. Some examples of data collection expectations in the *GAISE Report* include conducting a census, understanding variability, and conducting simple experiments with nonrandom assignment of treatments (Franklin et al., 2007, p. 23). Of the 1,711 GLEs in this study, 423 (slightly less than 25%) contain an explicit expectation of data collection (Type I Collect Data GLEs) or contain an expectation that students understand the effects of the decisions made at this stage (Type II Collect Data GLEs). Type I Collect Data GLEs account for 351 (approximately 83%) of the Collect Data GLEs. The number of Type I Collect Data GLEs increases until grade 3. Then, starting in grade 4, the total number of Collect Data GLEs continues an upward trend, while the number of Type I Collect Data GLEs decreases. This is due to an increasing focus in grades 4 through 8 on Type II activities such as evaluating a sampling method or sample. Every state in this study contains at least one Collect Data GLE. New Mexico has the largest number of Collect Data GLEs (20 GLEs).

Of the 351 GLEs that expect students to collect data, 159 (45%) specify or suggest collection methods. The most common strategy named was experiment, followed by survey, observations, and interviews. In addition, 21 of the 351 Type I Collect Data GLEs expect students to collect a sample. Some Type II Collect Data GLEs expect students to evaluate or understand a data collection method or sample. In total, 106 of the 423 Collect Data GLEs (approximately 25%) were coded as Type II. The two most common forms of these Type II GLEs are Evaluating a Characteristic and Evaluating a Method. An example of the former is, "Determine whether or not a sample is biased" (Tennessee, grade 6), while an example of the latter is, "Analyze how data collection methods and sample size can affect the results of data sets." (Hawaii, grade 6). The most often mentioned characteristics of data or a sample (along with the number of appearances) are biased and unbiased (11), random (9), representative (6), convenience (5), response (5), missing (4), and error (2).

Analyze Data

In this section, we report the findings of the third component of the statistical process, Analyze Data. The set of GLEs summarized in this section includes 968 of the 1,711 GLEs (approximately 57%) coded for the entire process outlined in this analysis. Every state standards document includes at least one GLE that was coded into Analyze Data. The minimum number of such GLEs in any state is 9 compared to the maximum number of 61. The median and mode are both 19 Analyze Data GLEs per state. As we began an investigation of the GLEs in this section, two primary categories emerged: Numerical Representations (e.g., mode, range) and

visual representations (e.g., picture graphs and scatterplots). Also, Type I and Type II expectations are present within each of these categories. Type I expectations in this section include those GLEs that expect students to calculate a numerical representation or to construct a visual representation. Type II expectations include those that expect students to understand the meaning of the representation and/or to evaluate in some way the decision to use a specific numerical or visual representation.

The Type I Numerical Representation GLEs expect students to calculate measures of central tendency and dispersion. Mean, median, mode, and range are each represented in most states (at least 95%) and show an increasing pattern across K-8. In contrast, a much smaller number of states address quartiles or outliers in their GLEs (46% and 39% respectively). The most common subcategories of Type II Numerical Representation expectations are Meaning of Numerical Representation (37 GLEs) and Selecting Appropriate Numerical Representation (39 GLEs). These GLEs expect students to understand the benefits of each numerical representation and be able to make decisions regarding the best choice for a given situation.

The Type I Visual Representation GLEs expect students to construct more than 30 different visual representations across the 41 states, 12 of which are mentioned at least 30 times. The three most common visual representations are chart/table (184 GLEs), bar graphs (170 GLEs) and pictographs (137 GLEs). The most common subcategory of Type II Visual Representation GLEs is Comparing Visual Representations (119 GLEs). For example, fifth graders in Georgia are expected to "Compare and contrast multiple graphic representations (circle graphs, line graphs, bar graphs, etc.) for a single set of data and discuss the advantages/disadvantages of each."

Interpret Results

The fourth process component in the statistical process is interpreting results. It involves interpreting the analysis and relating the interpretation to the original question (Franklin et al., 2007). This final component of the statistical process is central to the argument of the importance of statistics education since much statistical information is prepared and packaged up to this point. It is up to the individual to be a competent consumer of statistical presentations and evaluate the information found in statistical summaries and either draw one's own conclusions, or assess the validity of another person's existing conclusions.

Of the 1,711 statistics GLEs, 867 (approximately 51%) were coded as Interpret Results. As in the preceding process components, these GLEs include both Type I and Type II GLEs. Type I GLEs include those that involve interpreting, comparing, and making conclusions, claims, inferences and generalizations. In comparison, Type II GLEs include those that expect students to evaluate the outcomes of Type I GLEs as well as to understand the uses and misuses of statistics. Approximately 70% (603 of 867) of the Interpret Results GLEs are Type I. Of these Type I GLEs, 380 make use of the words or phrases interpret from data, interpret from visual representations, or interpret from numerical representations. Ninety-nine Type I Interpret Results GLEs focus on comparing: comparing data sets, comparing information in visual representations, comparing numerical representations, and comparing samples with the population. There are 245 GLEs that require students to make predictions, claims, conclusions, generalizations, or inferences. Fifty-three of these GLEs require justification as well. Approximately 8% (66 of 867) of the Interpret Results GLEs were categorized as Type II, that is, GLEs that are evaluative and reflective on the outcomes of Type I GLEs as well as understanding the uses and misuses of statistics. These included expectations that students evaluate conclusions.

CONCLUSIONS

Statistics has an increasingly important role in the lives of young people (Franklin et al., 2000, p. 1). We set out to determine what states expect students to learn about statistics in grades K-8 in the USA. We used the *GAISE Report* as a framework for our analysis. During our examination of the K-12 standards documents of 41 states, we found 1,711 K-8 GLEs that were related to statistical work. An overwhelming majority of these (almost 87%) were coded in either the Analyze Data or Interpret Results process components. In addition, 423 GLEs (nearly

25%) explicitly expect students to collect data and 112 GLEs (nearly 10%) expect students to formulate a question that could be answered by collecting data.

Each process component contains a form of Type II expectation that requires students to go beyond the process of "doing" statistics. These typically expect students to describe or evaluate the process. In Formulate Questions, Type II GLEs expect students to understand how a question (on a survey or other instrument) can affect data. In Collect Data, Type II GLEs expect students to evaluate a sample (e.g., for bias) or to evaluate a sampling method. Type II GLEs in Analyze Data generally expect students to decide which representation or measure of central tendency or dispersion best describes the data. Finally, Type II GLEs in Interpret Data expect students to evaluate inferences or assess the validity of claims. Type II GLEs are much more common in Collect Data and Analyze Data than in Formulate Questions and Interpret Results (28% and 34% compared to 12% and 8%). Overall, 28% of the 1,711 Statistics GLEs were coded as Type II. Finally, the number of Type II GLEs increases across K-8.

There are several important implications for teacher education programs from this analysis. First, a holistic approach to the statistical process is needed in order for teachers to understand the importance of spending time assisting students with question formulation and data collection (this analysis found these process components to be underrepresented in the state standards). Second, teachers will need to be prepared to facilitate discussions with students around the Type II expectations present in the standards. That is, in many states (to varying degrees), statistics education has moved beyond calculating and constructing graphs. For example, Washington and New Mexico contain 59 and 46 Type II expectations respectively across K-8. Finally, Type II expectations are much more common in grades 5-8. It seems important that teachers preparing to teach in lower elementary grades understand that these types of evaluations can be discussed with all students (e.g., Why might it be fair to ask only people in your neighborhood what their favorite food is when determining what types of restaurants should be built in the town?).

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