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Guidelines for Assessment and Instruction in Statistics Education (GAISE) for Undergraduates

The Guidelines for Assessment and Instruction in Statistics Education (GAISE) report on the introductory undergraduate statistics course can be found in its entirety (including appendices with examples) at *http://it.stlawu.edu/~rlock/gaise/*. The six main recommendations and a list of goals for the introductory course are excerpted here.

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Recommendation 1: Emphasize statistical literacy and develop statistical thinking.

We define statistical literacy as understanding the basic language of statistics (e.g., knowing what statistical terms and symbols mean and being able to read statistical graphs), and understanding some fundamental ideas of statistics. Statistical thinking has been defined as the type of thinking that statisticians use when approaching or solving statistical problems. Statistical thinking has been described as understanding the need for data, the importance of data production, the omnipresence of variability, and the quantification and explanation of variability.

Recommendation 2: Use real data.

It is important to use real data in teaching statistics, for reasons of authenticity, for considering issues related to how and why the data were produced or collected, and to relate the analysis to the problem context. Using real data sets of interest to students is also a good way to engage them in thinking about the data and relevant statistical concepts. There are many types of real data including archival data, classroom-generated data, and simulated data. Sometimes hypothetical data sets may be used to illustrate a particular point (e.g., the Anscombe data illustrates how four data sets can have the same correlation but strikingly different scatterplots) or to assess a specific concept. It is important to only use created or realistic data for this specific purpose and not for general data analysis and exploration. An important aspect of dealing with real data is helping students learn to formulate good questions and use data to answer them appropriately based on how the data were produced.

Recommendation 3: Stress conceptual understanding rather than mere knowledge of procedures.

Many introductory courses contain too much material and students end up with a collection of ideas that are understood only at a surface level, are not well integrated and are quickly forgotten. If students don't understand the important concepts, there's little value in knowing a set of procedures. If they do understand the concepts well, then particular procedures will be easy to learn. In the student's mind, procedural steps too often claim attention that an effective teacher could otherwise direct toward concepts.
Recognize that giving more attention to concepts than to procedures may be difficult politically, both with students and client disciplines. However, students with a good conceptual foundation from an introductory course are well-prepared to go on to study additional statistical techniques

in a second course such as research methods, regression, experimental design, or statistical methods.

Recommendation 4: Foster active learning in the classroom.

Using active learning methods in class is a valuable way to promote collaborative learning, allowing students to learn from each other. Active learning allows students to discover, construct, and understand important statistical ideas and to model statistical thinking. Activities have an added benefit in that they often engage students in learning and make the learning process fun. Other benefits of active learning methods are the practice students get communicating in the statistical language and learning to work in teams. Activities offer the teacher an informal method of assessing student learning and provide feedback to the instructor on how well students are learning. *It is important that teachers not underestimate the ability of activities to teach the material or overestimate the value of lectures.*

Recommendation 5: Use technology for developing concepts and analyzing data.

Technology has changed the way statisticians work and should change what and how we teach. For example, statistical tables such as a normal probability table are no longer needed to find *p*-values and we can implement computer-intensive methods. We think that technology should be used to analyze data, allowing students to focus on interpretation of results and testing of conditions, rather than on computational mechanics. Technology tools should also be used to help students visualize concepts and develop an understanding of abstract ideas by simulations. Some tools offer both types of uses, while in other cases a statistical software package may be supplemented by web applets. Regardless of the tools used, it is important to view the use of technology not just as a way to compute numbers but as a way to explore conceptual ideas and enhance student learning as well. We caution against using technology merely for the sake of using technology (e.g., entering 100 numbers in a graphing calculator and calculating statistical summaries) or for pseudo-accuracy (carrying out results to multiple decimal places). Not all technology tools will have all desired features. Moreover, new ones appear all the time.

Recommendation 6: Use assessments to improve and evaluate student learning.

Students will value what you assess. Therefore assessments need to be aligned with learning goals. Assessments need to focus on understanding key ideas and not just on skills, procedures, and computed answers. This should be done with formative assessments used during a course (e.g., quizzes and midterm exams and small projects) as well as with summative evaluations (course grades). Useful and timely feedback is essential for assessments to lead to learning. Types of assessment may be more or less practical in different types of courses. However, it is possible, even in large classes, to implement good assessments.

III Goals for Students in an Introductory Course: What it Means to be Statistically Educated

Students should believe and understand why:

- Data beat anecdotes.
- Variability is natural and is also predictable and quantifiable.
- Random *sampling* allows results of surveys and experiments to be extended to the population from which the sample was taken.
- Random *assignment* in comparative experiments allows cause and effect conclusions to be drawn.
- Association is not causation.
- Statistical significance does not necessarily imply practical importance, especially for studies with large sample sizes.
- Finding no statistically significant difference or relationship does not necessarily mean there is no difference or no relationship in the population, especially for studies with small sample sizes.

Students should recognize:

- Common sources of bias in surveys and experiments.
- How to determine the population to which the results of statistical inference can be extended, if any, based on how the data were collected.
- How to determine when a cause and effect inference can be drawn from an association, based on how the data were collected (e.g., the design of the study)
- That words such as “normal”, “random” and “correlation” have specific meanings in statistics that may differ from common usage.

Students should understand the parts of the process through which statistics works to answer questions, namely:

- How to obtain or generate data.
- How to graph the data as a first step in analyzing data, and how to know when that’s enough to answer the question of interest.
- How to interpret numerical summaries and graphical displays of data - both to answer questions and to check conditions (to use statistical procedures correctly).
- How to make appropriate use of statistical inference.
- How to communicate the results of a statistical analysis.

Students should understand the basic ideas of statistical inference:

- The concept of a sampling distribution and how it applies to making statistical inferences based on samples of data (including the idea of standard error)
- The concept of statistical significance including significance levels and *p*-values.
- The concept of confidence interval, including the interpretation of confidence level and margin of error.

Finally, students should know:

- How to interpret statistical results in context.
- How to critique news stories and journal articles that include statistical information, including identifying what's missing in the presentation and the flaws in the studies or methods used to generate the information.
- When to call for help from a statistician.