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GAISE Into the Future: Updating a Landmark Report for an Increasingly Data-Centric World

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Background

- The **Guidelines for Assessment and Instruction in Statistics Education** (GAISE) were originally endorsed by ASA in 2005. The guidelines included a PreK-12 report and a college-level report intended for introductory statistics courses.

- In 2012, then chair of the Section on Statistical Education, Brad Hartlaub, assembled a new committee to consider updating the GAISE College Report in light of changes in the field within the last decade.

  – The committee has been working consistently on updating the report for the past two years, with the goal of having a full draft ready in late 2015.

What has changed since 2005?

- Technology
- Classroom delivery formats (e.g., online courses, MOOCs, the flipped classroom)
- Big Data
- Emergence of the Data Science field
- Emphasis on Randomization-based methods

What has changed since 2005?

- Guidelines for how statistics is taught in K-12 settings (i.e., the GAISE PreK-12 report) and student-preparation before the college-level course (Common Core State Standards)
- AP Statistics enrollments: Close to 197,000 students took the AP Statistics Exam in 2015 (compared to 76,786 in 2005)
- The establishment of the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE)
- New conferences on teaching statistics (USCOTS and eCOTS), new assessment resources (e.g., ARTIST) and new assessments (e.g., CAOS)
- A new journal: *Technology Innovations in Statistics Education*

What has changed since 2005?

- Report on Research Priorities in Statistics Education (2012)
- ASA/MAA joint statement on Qualifications for Teaching an Introductory Statistics Course (2014)
- Curriculum Guidelines for Undergraduate Programs in Statistical Science (2014)
- Statistical Education of Teachers (SET) report (2015)
- 2015 CUPM Guidelines: Statistics Program Area Study Group Report

Current Structure of the GAISE College Report

- Executive Summary and Introduction
- Goals for Students in an Introductory Course: What it Means to be Statistically Educated

Current Structure of the GAISE College Report

- Six Recommendations for Teaching the Introductory Statistics Course:
  - Emphasize statistical literacy and develop statistical thinking
  - Use real data
  - Stress conceptual understanding, rather than mere knowledge of procedures
  - Foster active learning in the classroom
  - Use technology for developing conceptual understanding and analyzing data
  - Use assessments to improve and evaluate student learning

- Four appendices
  - Examples of activities and projects
  - Examples of assessment items
  - Example of using technology
  - Examples of naked, realistic, and real data

Updating the Six Recommendations

- We feel strongly that the original six recommendations have stood the test of time. However, we propose making some minor changes to wording, and we are debating making bigger changes to Recommendation #1:

    1) emphasize statistical literacy and develop statistical thinking*

    2) use real data **with a context and a purpose**

    3) focus on conceptual understanding, rather than **application** of procedures

    4) foster active learning

    5) use technology for developing conceptual understanding and **for** analyzing data

    6) use assessments to improve **as well as to** evaluate student learning

*Is it clear what is meant by "statistical literacy" and "statistical thinking"? Should we add definitions? Should we reduce to just "statistical thinking"? Can we get the point across in a different way altogether?

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Proposing Two New Emphases

- In the **Introduction**, we would like to suggest emphasis on two new areas within the Introductory Statistics course:
  - Teach statistics as an investigative inquiry
  - Provide students with experience with multi-variable thinking

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Goals

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Original GAISE
and Proposed Revisions

Students should recognize:

- Common sources of bias in surveys and experiments
- That words such as “normal," “random,” and “correlation” have specific meanings in statistics that may differ from common usage

Students should become intelligent readers of statistically-based results.
Specifically, they should know how to:

- Identify the variables in a study and their measurement units (or take note if units have not be specified.)
- Identify the subjects (cases) of a study and explain whether their responses are mutually independent, as required by many inference methods.
- How to determine the population to which the results of statistical inference can be extended, if any, based on how the data were collected
- Identify the population to which the results of an analysis can be extended, and to recognize who has been omitted from a study.

Students should become intelligent readers of statistically-based results.
Specifically, they should know how to:

- Read and interpret displays of data and statistical results and recognize inappropriate or misleading displays.
- 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)
- Determine when a cause-and-effect inference can be drawn from an association based on how the data were collected.
- Recognize whether the data can reasonably support the conclusions proposed for an analysis, for example, by examining the likely distribution of residuals or showing whether a linear relationship is likely to be obtained when that is assumed by the analysis.

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

- How to obtain or generate data
- Demonstrate how to obtain or generate data relevant to the question
- 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
- Show how to graph data as a first step in an analysis, and recognize when that's sufficient to answer the question of interest.

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

- How to interpret numerical summaries and graphical displays of data—both to answer questions and to check conditions (to use statistical procedures correctly)
- Examine numerical summaries and graphical displays of data—both to answer questions and to check conditions (to use statistical procedures correctly.)

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

- How to make appropriate use of statistical inference
- Demonstrate how to make appropriate use of statistical inference.
- How to communicate the results of a statistical analysis
- Demonstrate how to communicate the results of a statistical analysis.

Students should recognize and distinguish the basic ideas of statistical inference, including:

- The concept of a sampling distribution and a randomization distribution, and how these are used to making statistical inferences based on sample or experimental data
- The concept of standard error of a statistic.
- The concept of statistical significance, including p-values and significance levels.
- The concept of a confidence interval, including the interpretation of confidence level and margin of error.
- The abilities and limitations of statistical models for making predictions.

Students should participate in discussions of ethics relevant to statistics, including:

- privacy, confidentiality, and data security.
- IRBs and appropriate research on human and animal subjects.
- A statistician’s obligation to tell the truth about a data analysis.

Students should have an appreciation of, and some experience with, the use of computers in statistics, including:

- An acquaintance with typical computer output for standard statistics methods.
- An appreciation for the value of computer-based simulation to understand random behavior.
- Recognition of standard sources of data online.
- Experience using statistics software and interpreting the results of an analysis.

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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

Streamlining the Intro Stats Course

Why is Intro Stats required? Other fields want their students to:

- ✓ Think scientifically and to deal with statistics in their own disciplines.
- ✓ Be able to read research literature with a critical eye.
- ✓ Be able to understand what was studied, what was concluded, and how as (eventual) professionals they should judge the conclusions.

Streamlining the Intro Stats Course
Consider omitting or cutting back:

- Probability Theory
- Constructing plots by hand
- Basic statistics: Histograms, pie charts, bar charts, boxplots, scatterplots, means, medians, standard deviations; all are in the Common Core
- Advanced training on a statistics package (e.g., SAS certification, R programming)
- Drills with z-, t-, chi-square, and F tables.

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NEW
(sort of)

Appendix: Evolution of the Introductory Statistics Course and Development of Statistics Education Resources

Team working on updates:

Beverly L. Wood, Embry-Riddle Aeronautical University

Introduction

The GAISE project was funded by a member initiative grant from the ASA in 2003 to develop ASA-endorsed guidelines for assessment and instruction in statistics in the K–12 curriculum and for the introductory college statistics course.

Our work on the college course guidelines included many discussions over email and in-person small group meetings. Our discussions began by reviewing existing standards and guidelines, relevant research results from the studies of teaching and learning statistics, and recent discussions and recommendations regarding the need to focus instruction and assessment on the important concepts that underlie statistical reasoning.

History and Growth of the Introductory Course

The modern introductory statistics course has roots that go back a long way, to early books about statistical methods. R. A. Fisher's *Statistical Methods for Research Workers*, which first appeared in 1925, was aimed at practicing scientists. A dozen years later, the first edition of George Snedecor's *Statistical Methods* presented an expanded version of the same content, but there was a shift in audience. More than Fisher's book, Snedecor's became a textbook used in courses for prospective scientists who were still completing their degrees; statistics was beginning to establish itself as an academic subject, albeit with heavy practical, almost vocational emphasis. By 1961, with the publication of *Probability with Statistical Applications* by Fred Mosteller, Robert Rourke, and George Thomas, statistics had begun to make its way into the broader academic curriculum, but here again, there was a catch: In these early years, statistics had to lean heavily on probability for its legitimacy.

During the late 1960s and early 1970s, John Tukey's ideas of exploratory data analysis brought a near-revolutionary pair of changes to the curriculum: freeing certain kinds of data analysis from ties to probability-based models so that the analysis of data could begin to acquire status as an independent intellectual activity and introducing

	1970	2000	2010
CBMS, 2-year	27%	74%	100+%

	1997	2000	2014
AP Test Takers	7500		184,173

Influential Documents:

- *Heeding the Call for Change*
- *NSF survey*
- *GAISE – college and PK12 reports*
- *Common Core Standards*

Completely New Subsection:
The Emergence of Statistics Education Research and Teaching Resources

- Professional organizations (ASA, MAA, AMATYC)
- Consortium for the Advancement of Undergraduate Statistics Education CAUSE
- Academic Conferences
- Refereed Journals

Our question to you:

Are there any additional resources that should be referenced?

Your questions to us:

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NEW
(definitely)

Appendix: Examples of Applications in Different Classroom Environments

Team working on updates:

Ginger Rowell, Middle Tennessee State University

Beverly L. Wood, Embry-Riddle Aeronautical University

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Assignment:

"Creating an Appendix of the document to discuss how different delivery methods

- face-to-face – small, medium, large, huge (acknowledge the unique difficulties and emerging research)
- flipped
- online
- team based

or other contemporary approaches could follow the GAISE guidelines."

Cooperative Learning

A cluster of teaching/learning techniques (with a variety of names and purposes) that involve students working together can provide opportunities for implementing GAISE recommendations into statistics courses. Team-based (St. Clair & Chihara, 2012), student-driven (Sovak, 2010), cooperative (Garfield, 1993) or collaborative (Roseth, Garfield, & Ben-Zvi, 2008) learning, and guided investigations (Bailey, Spence, & Sinn, 2013) have nuances as outlined in the given references but all come down to opportunities to provide active learning in the classroom and use real data, often necessitating the use of technology to analyze it. The actual tasks assigned to small groups of students might incorporate the remaining recommendations by focusing on statistical thinking and conceptual understanding.

Resources:

Bailey, B., Spence, D. J., and Sinn, R. (2013). Implementation of Discovery Projects in Statistics, Journal of Statistics Education 21(3).
[NSF-funded curriculum available at http://faculty.ung.edu/DJSpence/NSF/materials.html]

Garfield, J. (1993). Teaching Statistics Using Small-Group Cooperative Learning, Journal of Statistics Education (1)1.

Roseth, C. J., Garfield, J. B., and Ben-Zvi, D. (2008) Collaboration in Learning and Teaching Statistics, Journal of Statistics Education (16)1.

Sovak, M.M. (2010) The Effect of Student-Driven Projects on the Development of Statistical Reasoning (Doctoral Dissertation). Retrieved from http://iase-web.org/Publications.php?p=Dissertations

St. Clair, K. and Chihara, L. (2012). Team-Based Learning in a Statistical Literacy Class, Journal of Statistics Education 20(1).

Example #1 - Histogram Comparisons

Each students is assigned a pair of histograms (out of four such pairs) for which they must determine which has more variability. They then discuss their reasoning with a partner until consensus is gained on both pairs of histograms. New partnerships are made and each student must explain the reasoning to the new partner for both their own and the original partner's histograms. In the end, every member of the foursome has four well-reasoned examples for determining the relative size of variability. Active learning and a conceptual understanding of variability are inherent in this activity.

Inspired by Roseth, Garfield, & Ben-Zvi (2008)

Description

References

Example

Current organization:

- Face-to-face
  - Small
  - ~~Medium~~
  - Large
  - Huge
- Flipped
- Online/hybrid/MOOC
- Cooperative learning

Our question to you:

Are there any additional delivery methods that should be included?

Your questions to us:

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Appendix: Activities, Projects, and Data Sets

Team Working on Updates:
John Gabrosek, Grand Valley State University
Robin Lock, St. Lawrence University

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Applicable GAISE Recommendations

- Recommendation 2: Use real data
- Recommendation 4: Foster active learning in the classroom

How have you used the GAISE Report?

- “I try to use more real world data”
- “gradually incorporating projects that involve working with real world data”
- “used it to structure courses and plan activities for students”
- “used suggestions…involving the use of statistical software, applets, real data examples, and homework using real data in both introductory and upper level courses”

Desirable Characteristics of Class Activities – GAISE 2005

1. The activity should mimic a real-world situation. It should not seem like "busy work." For instance, if you use coins or cards to conduct a binomial experiment, explain some real-world binomial experiments that they could represent.
2. The class should be involved in some of the decisions about how to conduct the activity. They don't learn much from following a detailed "recipe" of steps.
3. The decisions made by the class should require knowledge learned in the class. For instance, if they are designing an experiment they should consider principles of good experimental design learned in class, rather than "intuitively" deciding how to conduct the experiment.
4. If possible, the activity should include design, data collection and analysis so that students can see the whole process at work.
5. It is sometimes better to have students work in teams to discuss how to design the activity and then reconvene the class to discuss how it will be done, but it is sometimes better to have the class work together for the initial design and other decisions. It depends on how difficult the issues to be discussed are, and whether each team will need to do things in exactly the same way.
6. The activity should begin and end with an overview of what is being done and why.
7. The activity should be fun!

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Desirable Characteristics of Class Activities – GAISE 2016

Structure and timing...

- Self-contained and complete
- Ending an activity

Choosing data...

- Relevance
- Contextual background

If the activity involves collecting/generating data...

- Design decisions and data collection

Desirable Characteristics of Class Activities – GAISE 2016

Working in groups...

- Team work
- Role of groups in design decisions

Sharing activities...

- Creating an activity for sharing
- Resources for activities

Examples of Projects and Activities – GAISE 2005

- **Activities that could be improved**
  - Pepsi vs. Coke activity
  - Central Limit Theorem activity

- **Additional examples of activities and projects**
  - Data gathering and analysis: A class of projects
  - Team constructed questions about relationships
  - Comparing manual dexterity under two conditions

- **Examples of naked, realistic, and real data**

Examples of Projects and Activities – GAISE 2016

- **In-class data collection and analysis activities**
  - Leg length and stride length
  - Randomization test for a difference in means – cola and calcium
  - Comparing manual dexterity under two conditions

- **Examples of naked, realistic, and real data**
  - Naked data
  - Realistic data
  - Real data
  - Real data, from a real study

Examples of Projects and Activities – GAISE 2016

- **Data and stories available on the web**
  - Ames, Iowa real estate data (JSE)
  - US road location data (STEW)

- **Websites with data**

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Discussion Question:

Do activities need to involve “important” data, or are activities that illustrate important statistical skills and concepts using less “important” data valuable?

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Appendix: Examples of Using Technology

Team Working on Updates:

Robert Carver, Stonehill College

Megan Mocko, University of Florida

GAISE Recommendations

- Directly Related Guideline
  - #5 Use technology for developing conceptual understanding and for analyzing data

- Additionally, technology can be used for:
  - #2 Use real data
  - #4 Foster active learning

GAISE 2005

- One example of using technology
  - A technology based simulation to examine the effectiveness of treatments for cocaine addiction
    - "A study on the treatment of cocaine addiction described the results of an experiment comparing two drugs for helping addicts stay off cocaine (D.M. Barnes, "Breaking the Cycle of Cocaine Addiction", *Science*, Vol. 241, 1988, pp. 1029-1030.) . . ."

GAISE 2016 (proposed)

Examples of Technology

- Interactive applets
- Real time response systems
- Statistical software
- Accessing real experimental data online
- Accessing real survey data online
- Using games and other virtual environments

Our focus for the Technology Appendix for GAISE 2016 (proposed)

- Software brands are avoided as much as possible. No particular software is endorsed.
- No exact instructions for technology used.
- Choose learning goal first, then technology.
- Instructors asked to consider appropriateness.
  - Is the technology appropriate for the students or does the technology bog them down hindering understanding and learning?
- Examples include links to statistical education literature that inspired the activity, best practices and teaching tips.

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Interactive Applets

- Commonly discussed applet topics
- Uses
- Best practices and ideas from statistics education literature
- Future direction of applets and interactive visualizations
- Examples
  - Example 1: Using statistical software applets to perform randomization and bootstrapping techniques (refer to activities section).
  - Example 2: Creating a story board, video or cartoon about findings from an applet
  - Example 3: Exploring misconceptions about sampling distributions by using an applet

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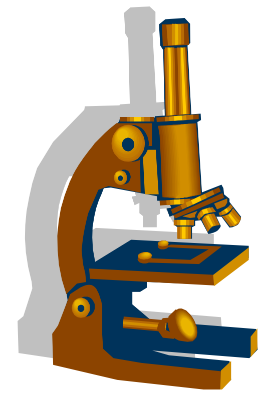
Real Time Reponses

- Multiple Methods:
  - clickers, Learning Catalytics, Google Forms, BYOD online polling
  - Etherpad, Google Docs
- Best practices and references to statistics education literature
- Examples
  - Example 1: Using real time responses as an example of how to bring attention to a misconception
  - Example 2: Using a real time response as a way to guide a student's experience with an applet
  - Example 3: Illustrating the sampling distribution of the sample proportion

Teaching Concepts with Statistical Software

- Discussion of using statistical software to do statistical computation to free up class time to discuss concepts.
- References are given for research articles on this topic
- Examples
  - Example in class activity to illustrate the principle of “confidence” by each student selecting their own random sample and calculating a confidence interval.
- Discussion of using software to create a wider variety of visualizations
  - Short example using Gapminder
  - Short example using the world map in JMP’s graph builder
- Discussion of using software for reproducibility and better, clear student assignments
  - Example of using R Markdown for a class homework assignment

Accessing Real Experimental Data Online



- Background of Open Science, Science Commons and Citizen Science Movements
- Example: What makes a YouTube video funny?

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Accessing Real Survey Data Online

- Discussion of data available on the General Social Survey website
- Example activity using output from the general social survey

Using Games and Other Virtual Environments

- Related classroom topics
  - Getting real data or gathering virtual data (i.e. Island by Michael Bulmer)
  - Experimental design
  - Statistical concepts (students must master a statistical concept to move ahead)
- List of inspiration articles from statistical education research
- Example: Design an experiment to investigate a research question that they have about a game.

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Discussion / Reaction / Questions

- What else should be added?

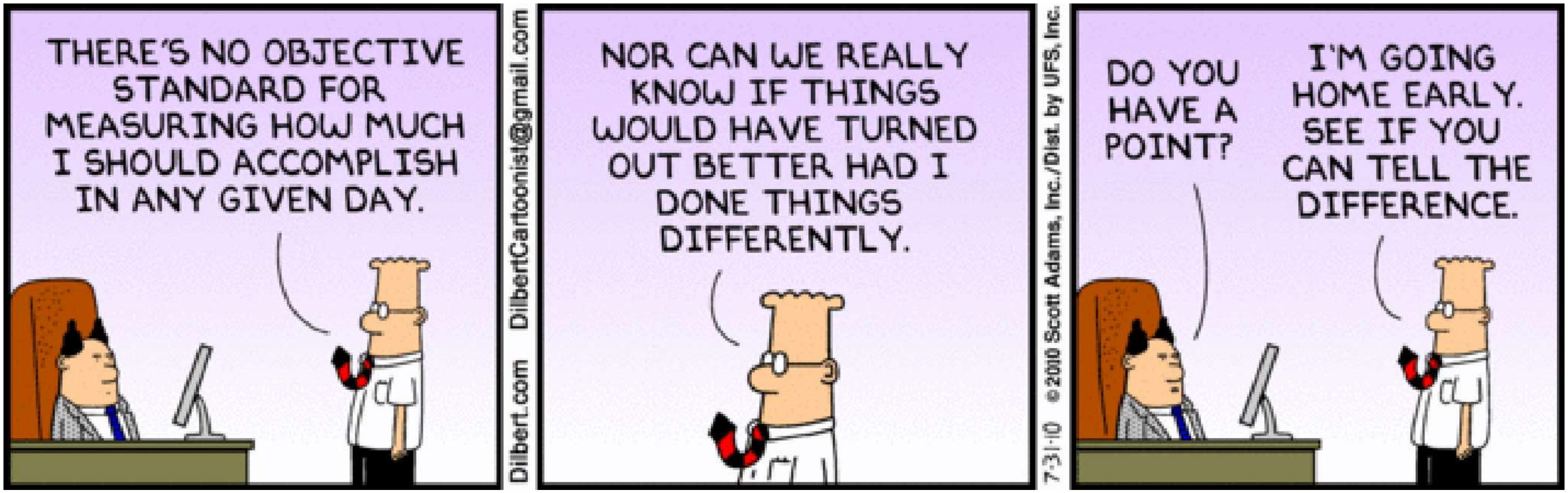
- What should be reduced or removed?

- How strong a role should technology play in the Intro Stats curriculum?

Appendix: Assessment

Team Working on Updates:
Jeff Witmer and Nick Horton
Presented by Rob Carver

Everyone's favorite topic…



How to assess progress and impacts on learning?

Appendix: Examples of Assessment Items

- **Goals of revision**:
  - Maintain focus on conceptual understanding rather than computation
  - Assist faculty in selecting, revising & creating assessment questions
  - Provide numerous exemplars
  - Permit both formative and summative assessment
  - Include presentations and projects

2005 version of Appendix

- Examples of Assessment Items with Problems and Commentary about the Nature of the Difficulty (3)
- Examples Showing Ways to Improve Assessment Items (4)
- Additional Examples of Good Assessment Items (28)

Current Draft of Appendix

- Exemplars of Good Questions (6)
- Examples of Assessment Items with Problems and Commentary (3)
- Examples Showing Ways to Improve Assessment Items (6)
- Additional Examples of Good Assessment Items (32)
- Examples of Assessments for Presentations and Projects

Assessment Appendix: By the Numbers

	2005 Report	Draft Revision
Pages	17	23
Categories	3	5
Example Questions	35	$47 \pm \varepsilon$

Sample Exemplary Items

- Does everyone who scores below the median on this exam necessarily have a negative *z*-score for this exam? Explain.
- (after describing an experiment and reporting *p*-value):
  - Summarize your conclusion from this *p*-value. Be sure to address the issue of causation as well as the issue of significance. Also justify your conclusion.

Items with Problems + Commentary

Assessment items to avoid using on tests:

- *traditional True/False,*
- *pure computation without a context or interpretation,*
- *items with too much data to enter and compute or analyze, or*
- *items that only test memorization of definitions or formulas.*

Examples Showing Ways to Improve Items

Traditional True/False

The size of the standard deviation of a data set depends on where the center is.

True or False

Examples Showing Ways to Improve Items

Improved Version

Does the size of the standard deviation of a data set depend on where the center is located?

A. Yes, the higher the mean, the higher the standard deviation.

B. Yes, because you have to know the mean to calculate the standard deviation.

C. No, the size of the standard deviation is not affected by the location of the distribution.

D. No, because the standard deviation only measures how the values differ from each other, not how they differ from the mean.

Discussion/ Reaction/ Questions?

- Have you used this part of the current GAISE report?
- What else should be added?
- What should be tightened/ discarded?