

## Exercises and Questions

### for Electronic Assessment of Statistical Concepts

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In the United States most introductory courses in applied statistics emphasize definitions, computations, and procedure. Hence instructors in these Stat 101 courses may ask their students to define a median, to use a formula to compute a correlation coefficient, or to follow a six-step procedure to test a pair of hypotheses. With the current technology there is no need for students to memorize definitions, as they have done in the past. By using the Internet in a wireless environment (or by using the Help available in many statistical software packages), students may easily obtain a definition of any term found in a first course. With today's electronic calculators (or statistical software), they do not need to use a formula for computation. Nor do they need to follow a complicated procedure to obtain an estimate of a p-value from a table, when a sequence of clicks produces an exact p-value.

Instead most statistical educators recommend that Stat 101 should stress concepts. It should not be a course whose learning objectives are blind memorization, elementary arithmetic computation, and successful implementation of procedures. One influential report that makes this recommendation is the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report* (Garfield et al (2005)). The third of its six recommendations states that the course should “stress conceptual understanding rather than mere knowledge of procedures”. Included in this report are references to some important statistical concepts such sampling distributions, statistical significance, and confidence intervals, but there is no definition of a statistical concept. From conversations with many statistical educators in recent years, the author believes that such an idea is similar to United States Supreme Court Justice Potter Stewart's explanation of “hard-core” pornography: “I shall not today attempt further to define the kinds of material I understand to be embraced . . . [b]ut I know it when I see it . . .”. In an attempt to determine the core statistical concepts, a survey of 57 statisticians was administered at the 2004 Joint Statistical Meetings (McKenzie (2004)). The most mentioned core concepts were variability, association vs. causation, randomness, significance (statistical vs. practical), data collection methods (experiments, observations, surveys) and sampling distributions (law of large numbers, CLT (central limit theorem)).

But, even when such concepts can be identified, they are rarely emphasized for a number of reasons. First, concepts are harder to teach (and to learn). Second, most introductory applied statistics textbooks in general education and business and economics do not accentuate such ideas (McKenzie and Goldman (2002)). Nor do these texts, along with their study guides and other supplements, provide many conceptual exercises for students to learn such ideas. For example, consider one best-selling business and economics text, Berenson, Levine, and Krehbiel (2006). Even though the word, concepts, is found in its title, there are few conceptual exercises in this text. A typical chapter contains problems (exercises) after each section and chapter review problems at the end of each chapter. There are two types of section problems. Almost all of the ‘Learning the Basics’ problems are definitions, e.g., “What does  $1 - \beta$  represent?”, or computations of artificial data, e.g., “Compute the population mean.”. The “Applying the Concepts” problems are usually a sequence of computations, often of real data. The “Checking Your Understanding” problems present in the first portion of the Chapter Review Problems are similar to the “Learning the Basics” problems, while the second portion of these problems are more “Applying the Concepts” problems. Also present at the end of

the Chapter Review Problems are “Report Writing Exercises”, none of which dealt with concepts.

Recently publishers have begun bundling electronic assessment systems with their texts. These are the 21st-century’s test banks. And, while they are numerous benefits, to using such systems for homework, quizzes, and review, these systems contain even fewer conceptual exercises. For example, almost all of the PH Grade ASSIST exercises bundled with Berenson, Levine, and Krehbiel are either multiple choice definitions or computations. One of the reasons for this disappointing development is the difficulty in handling textual answers in contrast to numerical answers. Another reason is difficulty in programming graphical displays into electronic assignment systems. Such displays are invaluable in explaining statistical concepts. The typical exercises and questions developed by users for electronic assessment systems are also non-conceptual for many of the same reasons. In addition, such developers do not have a bank of conceptual exercises to reference. One notable exception is the set of questions developed by the Assessment Resource Tools for Improving Statistical Thinking (ARTIST) Project (Garfield, delMas, and Chance (2006)).

Examples of strong conceptual exercises and questions for electronic assessment from ARTIST, along with examples of other strong exercises and questions from other sources, will be presented at ISI 2007. For example, here is one example of such a conceptual exercise with its numerous options within brackets:

A <professor, researcher, statistician, student> decides to analyze a set of random data. <He, She> calculates a p-value from a two-tailed one-sample hypothesis test for the mean <height, weight> of a population of <people, animals> in which <he, she> does not know its population standard deviation. What would happen to this p-value if

1. the size of the population <decreases, increases> and everything else is held constant?  
It <decreases, stays the same, increases>.
2. the difference between the sample and hypothesized means <decreases, increases> and everything else is held constant?  
It <decreases, stays the same, increases>.
3. the value of the test statistic <decreases, increases> and everything else is held constant?  
It <decreases, stays the same, increases>.
4. the sample standard deviation <decreases, increases> and everything else is held constant?  
It <decreases, stays the same, increases>.
5. the sample variance <decreases, increases> and everything else is held constant?  
It <decreases, stays the same, increases>.

Note the lack of numbers in this conceptual question. It is similar to questions presented by McKenzie and Goldman (2006).

## REFERENCES

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### **ABSTRACT**

Most introductory applied statistics courses in the United States do not stress concepts. Instead they emphasize definitions, computations, and procedures. This is not the best way to teach statistics with today's powerful and easy-to-use statistical packages. Hence, the rationale for the third of the six recommendations found in the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report. One reason that the current situation exists is that textbooks rarely deal with conceptual issues. Nor do the exercises found in these textbooks and their study guides. The same is true of the questions present in their supplementary test banks. In recent years the major publishers have included similar non-conceptual questions in their electronic assessment systems. These exercises and questions are assigned for homework, used for review, and given in quizzes and, to a lesser degree, examinations. This paper starts with a brief summary of the type of exercises and questions found in popular textbooks and their supplements. Then there is a thorough examination of the exercises and questions present in one publisher's electronic assessment system. Finally, suggestions for exercises and questions to improve the learning of statistical concepts in such systems are presented.