The introductory applied statistics course taken by many thousands of undergraduate students has undergone a transformation over the past 25 years. Changes in what we teach, how we teach, and how we assess have impacted introductory statistics courses at institutions worldwide. In this article we shift focus from what we teach and how we teach to when we teach. We propose changes to the sequence in which core statistical concepts are presented in an introductory applied statistics course. The proposed ordering of topics repeats the sequence of descriptive summaries—probability theory—statistical inference several times throughout the course in various contexts.

KEY WORDS: Learning theory; Pedagogy of statistics; Statistics education

1. INTRODUCTION

The introductory applied statistics course has undergone changes at many institutions as instructors become aware of and begin to implement ideas from reform-based curricular projects. For example, the GAISE College Report (Garfield et al. 2005) gives six recommendations for the teaching of introductory statistics. David Moore’s article “New Pedagogy and New Content: The Case of Statistics” (1997) discusses reform of pedagogy, content, and technology in the teaching of statistics. Moore’s article and the GAISE guidelines have received considerable attention. Such reform-based curriculum projects have led to changes in what we teach (e.g., Ballman 1997; Hirsch and O’Donnell 2001; Keeler and Steinhorst 2001; Schafer and Ramsey 2003), how we teach (e.g., Rumsey 1998; Garfield 2002; Doane 2004; Nordmoe 2007; Roseth, Garfield, and Ben-Zvi 2008), and how we assess (Konold 1995; Weinberg and Abramowitz 2000; Chance 2002; Froelich, Stephenson, and Duckworth 2008).

The ordering of the topics we select to teach in an introductory statistics course has largely been left out of this discussion; however, the concept of resequencing topics is not new.

For example, Malone witnessed a friendly debate between Beth Chance and Allan Rossman in the Spring of 1998 on the sequencing of topics for an introductory statistics course at the Western Statistics Teachers’ Conference. Chance and Rossman (2001, pp. 140–144) expanded upon this debate and presented their work more formally in an article titled “Sequencing Topics in Introductory Statistics: A Debate on What to Teach When.” Chance and Rossman debated issues such as should we teach confidence intervals or tests of significance first and should we teach inference for proportions before inference for means. Wardrop (1995) drastically reordered topics in his textbook Statistics: Learning in the Presence of Variation. The fact that Wardrop introduced hypothesis testing in chapter 2 and did not introduce a dot plot or histogram until chapter 12 illustrates the degree to which the presentation of topics was changed. Chance and Rossman (2006) included some inference topics early in their text designed for post-calculus students. Cobb and Moore (1997) discussed the ordering of data production, data analysis, and inference in the introductory statistics course. They argued that the course should begin with data analysis and suggested that data production, design issues, and issues related to sampling serve as the bridge to statistical inference. This article expands upon these earlier works and gives specific examples of the implementation at two different universities.

Descriptive statistics, data collection, and statistical inference are topics covered in most introductory applied statistics courses. The statistical inference procedures covered vary some, but typically include one-sample and two-sample inference on means and proportions, the $\chi^2$-test of independence, analysis of variance, and regression. Table 1 gives a rough outline of the typical order of topics found in the Table of Contents of several commonly used textbooks (e.g., Moore and McCabe 2005; Agresti and Franklin 2007; Utts and Heckard 2007). The syllabi included as examples by the CollegeBoard (apcentral.collegeboard.com/apc/public/courses/syllabi/index.html) for the advanced placement statistics course generally follow this ordering of topics as well. There are exceptions to this ordering. For example, some textbooks wait to present bivariate data until later in the semester whereas others present hypothesis testing before confidence intervals.

The traditional sequence of topics (see Table 1) has three problems.

(1) The traditional sequence of topics does not follow the scientific process. Popper (1959, p. 27) described the scientific method, “A scientist, whether theorist or experimenter, puts forward statements, or systems of statements, and tests them step by step. In the field of the empirical sciences … he constructs hypotheses, or systems of theories, and tests them against experience by observation and experiment.” The natural progression of the scientific process (i.e., research question to data collection to data summaries to inference) is lost in the traditional

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sequence. Whereas we agree with Cobb and Moore (1997) that the process of data production to exploratory data analysis to inference is not linear, we do find the representation useful within the confines of a particular research question. The traditional sequence leads students to believe that statistical inference and its methods are separate from issues of design and exploratory data analysis because these topics are often disconnected in time.

(2) Students find the first part of the course (e.g., descriptive statistics and data collection) easy and, hence, are lulled into a false sense of security about their success in the course. When discussion of sampling distributions and statistical inference begins, many students are left gasping and never fully recover.

(3) The traditional sequence reinforces the belief that statistics is a matter of applying the correct formula to a problem or using software haphazardly to get an answer. Placing the more difficult topics of statistical inference in the latter part of the semester inevitably reduces the teacher to doing little else than providing the formula for the test statistic as she frantically attempts to complete the syllabus, or, worse yet, using software or technology as a “black box” to spit out a test statistic and a \( p \)-value with little discussion of what either means.

In this article we discuss an alternative approach to the sequencing of topics for an introductory applied statistics course that covers the same topics as in Table 1. In Section 2 we explain the philosophy behind an alternative sequence. We discuss an alternative sequence used by some faculty at Winona State University (WSU) in Section 3. In Section 4 we discuss an alternative sequence used by some faculty at Grand Valley State University (GVSU). Discussion and suggestions for best practices are given in Section 5.

### 2. PHILOSOPHY OF AN ALTERNATIVE SEQUENCE

The goal of this work is to consider a new sequence of topics for the introductory applied statistics course that improves student acquisition and retention of core statistical concepts. We do not debate the “correctness” of the list of topics given in Table 1, but consider only the ordering of these topics. The authors kept four principles in mind when developing an alternative sequence for the introductory statistics course.

**Principle 1: More Closely Mimic What a Scientist/Statistician Does**

Typically the first question a consulting statistician asks is, “Why didn’t you come to me before you collected data?” After coming to grips with the fact that this usually does not happen, the consultant begins to unravel the story behind the data. The unraveling of the story requires a statistician to consider the variables of interest, the number of variables being considered, and the type of variables (e.g., categorical or numerical). The story continues to unfold as the statistician considers the various research questions or goals of the study, issues related to the study design and/or data collection methods, appropriate methods for exploratory data analysis, and the use of appropriate statistical inference procedures when necessary. A statistician typically does not proceed with, “I will first complete all my graphs to answer the various research questions, then I will do all my numerical summaries for the various research questions, then I will compute the various confidence intervals for the various research questions, and lastly I will do the necessary and appropriate hypothesis tests for the various research questions.”

The analysis of data is not linear, nor does it follow the traditional sequence of topics in an introductory applied statistics course.
course. A statistician is much more likely to complete an entire analysis for one research question and then move onto the next research question.

**Principle 2: Get to Statistical Inference Earlier in the Semester**

Wardrop (1995) proposed a new sequence of topics that focused on introducing inference much earlier in the course. For example, he introduced hypothesis testing, complete with terminology and application, in chapter 2. To quote Wardrop, “I believe it is important to challenge students early in a course. An early introduction to hypothesis testing certainly has that effect!” (1995, p. xix).

**Principle 3: Follow What We Know From Learning Theory**

Psychologists and brain researchers believe that for retention and application of knowledge to new situations the spacing of repetitions in various contexts performs better than the massing of repetitions (Schmidt and Bjork 1992). Lovett and Greenhouse (2000) enumerated five learning principles from cognitive theory. Included is that learning occurs when students integrate new knowledge with existing knowledge. They also argued that as students are required to handle a heavier mental load that learning becomes less efficient.

**Principle 4: Teach Just Enough Probability to Get by**

Prior to the reform-based curricular changes in statistics, the introduction to statistics for most undergraduates was through a probability and statistics course that was heavy on the probability and light on the analysis of real data. As David Moore (2007, p. xiv) wrote, “Attempting to present a substantial introduction to probability in a data-oriented statistics course for students who are not mathematically trained is in my opinion unwise. Formal probability does not help these students master the ideas of inference . . . and it depletes reserves of mental energy that might be better applied to essentially statistical ideas.”

The alternative sequences proposed (see Sections 3 and 4) start with an introduction that covers data collection and basic probability, with approximately one week devoted to each topic. The probability section includes the basic idea of probability (e.g., subjective probability versus relative frequency probability), a brief introduction to probability distributions for discrete random variables (e.g., WSU includes the binomial distribution whereas GVSU includes only a general discussion of discrete random variables), and an introduction to probability distributions for continuous random variables (e.g., standard normal distribution). The probability discussions that take place serve as a bridge to finding and interpreting $p$-values from standard tests. Probability discussions not directly applicable to $p$-values are left as optional course content.

After the introductory material on data collection and probability, the proposed alternative sequences of topics incorporate these four principles by using a case-by-case approach to teach descriptive and inferential statistics. A case is defined to be a situation dealing with a specific type or types of variables relevant to a specific research question. For example, a research question may involve one quantitative variable (e.g., height), one categorical variable (e.g., gender), or two categorical variables (e.g., gender and presence/absence of pierced ears). The alternative sequence brings together the appropriate descriptive methods, sampling distributions, and inferential procedures specific to a case. This reconfigures the traditional sequence which is set up to complete all descriptive statistics, then all design and data collection issues, then all sampling distribution issues, and, finally, all inferential methods.

We present two alternative sequences developed independently by Chris Malone at Winona State University (Section 3) and John Gabrosek and Matt Race at Grand Valley State University (Section 4).

### 3. Winona State University Model

Winona State University (WSU) is a public liberal arts university located in Winona, MN. The Department of Mathematics and Statistics is the home of seven statisticians whose primary load involves teaching lower and upper division statistics courses. The Department of Mathematics and Statistics at Winona State University offers a wide variety of introductory statistics courses: (1) STAT 110: Introductory statistics for a general audience, (2) STAT 210: Calculus-based introductory statistics, (3) STAT 303: Introductory statistics for engineering majors, (4) STAT 305: Introductory statistics for science majors, and (5) STAT 601: Introductory statistics for individuals pursuing a masters degree in nursing. In addition to these introductory courses, the School of Business offers a two-course sequence in statistics and the Department of Psychology offers an introductory statistics course for their majors. The Department of Mathematics and Statistics offers about 20 sections of introductory statistics in the fall semester and 15 sections in the spring semester. A typical class size is 37 students.

#### 3.1 Genesis of Alternative Sequencing at WSU

The syllabus for most of the introductory statistics courses taught by the Department of Mathematics and Statistics at Winona State University is essentially the same with differences in the context of the examples used for instruction. In addition, the sequence in which the topics are presented has traditionally followed Table 1.

The often dismal student responses to the following assessment items for the hypothesis test: $H_0: \mu_1 = \mu_2$ vs. $H_A: \mu_1 \neq \mu_2$ caused Malone to reconsider the traditional sequence.

1. **Explain why we cannot simply reject $H_0$ when the sample mean from group 1 is different than the sample mean from group 2.**
2. **If we reject $H_0$, why would the confidence interval for $\mu_1 - \mu_2$ not contain zero?**

Under the traditional sequence of topics a correct response requires students to recall knowledge from various time points throughout the semester. For the first question, students must recall knowledge from the beginning of the course in which sample means were discussed, the middle of the course when sample-to-sample variation and sampling distributions were
discussed, and the end of the course when two-sample hypothesis tests were discussed. An incorrect response to the first question may be compounded by the fact that a student would get full credit for accurately contrasting sample means across groups when doing descriptive statistics. Typical conversations with students often lead to a statement like, “How come I cannot do this? You gave me full credit back on my second homework assignment when I did this.” The proposed ordering of topics puts the concepts that are necessary to answer such assessment items closer together in time. The second assessment item has been asked on a regular basis and Malone has observed a slight improvement in a student’s ability to give a correct response to this item. However, the evidence for improvement is anecdotal and it is not possible to attribute such improvements directly to the reordering of topics.

3.2 The WSU Model

An instructor’s ability to effectively present topics using an alternative sequence may be hindered by the textbook used for the course. Fortunately, at Winona State University, the instructor has some leeway in the choice of the textbook to be used for his course. Malone developed an initial set of course notes during the Spring 2005 semester to overcome the problem of jumping around in the textbook. These course notes continue to evolve, but the order in which topics are covered has remained mostly constant and is presented in Table 2.

The sequence of topics presented in Table 2 may appear to be missing material; however, this is not the case. Section I: Introduction includes some basic definitions, a discussion of data collection methods, the concept of random sampling or random assignment including its importance to drawing inferences, a discussion of the need for inferential methods, and a brief discussion of types of studies. Probability concepts are not presented as stand-alone ideas, but are integrated into the various sections as a tool for carrying out inferential procedures. For example, a student’s first exposure to probability is in Section II: One categorical variable, where the binomial distribution is utilized as the sampling distribution for a proportion. Additional concepts such as appropriate descriptive statistics, sample-to-sample variation, and sampling distributions are taught within a specific case (e.g., type of variable and number of variables). This alternative sequence more closely mimics how a statistician completes an analysis of data.

The alternative sequence permits the instructor to emphasize the major concepts (e.g., descriptive methods, sampling distributions, hypothesis testing, and confidence intervals) repeatedly throughout the entire semester, whereas the traditional sequence (see Table I) separates by several weeks the concepts necessary for completing an analysis for a particular case. Other instructors at Winona State University have adopted the sequence presented in Table 2 or have taught using variations of this sequence. These instructors continue to modify the sequence to best fit their teaching approach.

4. GRAND VALLEY STATE UNIVERSITY MODEL

Grand Valley State University (GVSU) is a mid-sized university (23,000+ students) that educates students in the tradition of the liberal arts. GVSU is located in and near Grand Rapids, MI. The Department of Statistics is home to 14 tenure-track faculty and more than a dozen adjunct and visiting faculty. Introductory applied statistics (STA 215) is taught exclusively by faculty from the Statistics Department. STA 215 fulfills the mathematical foundations requirement in the general education program. About 50 sections are taught during each of the fall and winter semesters and an additional 15 sections are taught during the spring/summer. Section enrollment is capped at 31 students. Approximately 4000 students take STA 215 each calendar year. Unlike many universities, GVSU does not offer separate sections of the introductory applied statistics course geared toward business majors, psychology majors, etc.

4.1 Genesis of Alternative Sequencing at GVSU

Historically, the introductory applied statistics course at Grand Valley (STA 215) progressed through the topics following a sequence that closely matches the order of topics presented in Table 1. Some variations to the traditional sequence at GVSU have included:

1. Faculty switching the order of I (exploring data), II (data collection), and III (randomness and probability). However, all faculty completed exploring data, data collection, and randomness and probability prior to any discussion of sampling distributions and statistical inference.

2. Faculty switching the order of the advanced topics (VII) and possibly skipping one or more of the advanced topics due to time constraints.

Faculty at Grand Valley have long decried that students perform poorly on statistical inference. Discussions among faculty on how to improve student performance are commonplace. Such discussions led the author (Gabrosek) and a GVSU student (Race) majoring in mathematics and minoring in statistics to spend Summer 2005 working to develop an alternative sequence for teaching the concepts in introductory applied statistics. The results of this summer research and subsequent work has led to the GVSU model for the sequencing of topics in an introductory applied statistics course.

4.2 The GVSU Model

The sequence decided upon by Gabrosek and Race is shown in Table 3. After introducing the basics of data collection and probability, the sequence consists of a case-by-case approach to the topics.

The GVSU model follows the four principles outlined in Section 2. Instead of waiting until the midpoint of the semester to
introduce statistical inference, students encounter the sampling distribution of the sample proportion by week 3 and have completed a z-test on the population proportion by week 5. Students logically progress through a case from descriptive statistics to hypothesis testing. This enables students to grasp the connection between graphical and numerical summaries of sample data, the assumptions underlying the analysis, and results of inference procedures.

Table 4 shows a more detailed outline of the topics covered in Case 2: One-sample quantitative data. The details for Case 2 show that students progress logically from data type, to graphical and numerical summaries, to the sampling distribution of $\bar{x}$, to the confidence interval and hypothesis test on $\mu$. The same ordering is followed within each of the seven cases. Statistics is taught as a connected body of knowledge for different cases. The process of completing an entire statistical analysis is reinforced multiple times in different settings throughout the semester.

Notice that the $t$-distribution is introduced in the context of estimating the population mean $\mu$. At this point in the course students are comfortable with the normal distribution both as a large-sample distribution for the sample proportion $\hat{p}$ and as the distribution of bell-shaped quantitative data. The extension to the $t$-distribution is straightforward.

More than half a dozen faculty at Grand Valley now teach introductory applied statistics using some modification of the GVSU model outlined in Table 3. Sequences differ in the ordering of Cases 1 through 7. Some faculty prefer to cover quantitative data before categorical data, thus switching the order of Cases 1 and 2. Gabrosek has modified the sequence so that he now covers the material in the order one-sample categorical data, one-sample quantitative data, two categorical variables, two quantitative variables (including regression), paired quantitative data, two independent samples quantitative data, and one-way analysis of variance. It is important that any modification retain the cyclical nature of progressing through the material as outlined in Table 4. The repetition of the process helps students to internalize important concepts and allows students to place new material within a connected body of knowledge more easily.

5. DISCUSSION

There are certainly advantages to teaching using an alternative sequence. The most prominent advantages are given here.

- More closely mimicking what a scientist/statistician does: Statisticians take the variable(s) of interest and proceed with an investigation from start to finish. Each case considers a research question, the study design and data collection methods, appropriate descriptive statistics, assumptions for an analysis, and any appropriate and necessary inferential procedures.

- Getting to statistical inference earlier in the semester: A case-by-case approach makes it easier to use projects in the classroom experience, and gives the students more time to absorb concepts such as confidence intervals and hypothesis testing.

- Following what we know from learning theory, by cycling through the same process over and over: The case-by-case approach allows instructors to cycle through the process of doing a complete statistical analysis many times throughout the semester. We have found that near the end of the semester, students often tell us the next step of a statistical analysis with minimal prompting. Also, students are better able to identify the similarities and differences between the cases which makes it easier to identify the most appropriate analysis for a given situation.

- Permitting assessment to be more formative and authentic: Because students have the necessary tools by the end of the fifth week for a complete statistical analysis of categorical data, homework problems and other assessment items can require students to design (and possibly carry out) data collection plans, summarize data, and draw inferences about a population. Holistic assessment complements the more segmented assessment typically done when following the traditional sequence of topics.

There are some drawbacks to using an alternate sequencing of topics in an introductory statistics class. The biggest disadvantage is centered on the textbook or lack thereof. The authors were unable to find a textbook to meet their needs. A content analysis of 17 of the most commonly used introductory texts found that: (1) all 17 texts had completed discussion of numerical and graphical summaries for both categorical and quantitative data prior to discussion of statistical inference (and the sampling distribution of either $\bar{x}$ or $\hat{p}$), and (2) most of the texts had a chapter or two chapters introducing confidence intervals that included both estimation of the population mean and the
population proportion prior to a separate chapter or chapters introducing hypothesis testing of means and proportions.

The investment of time for an instructor to implement an alternate sequence with an existing text depends on several factors. The textbook currently being used at GVSU is *Mind on Statistics* by Utts and Heckard. The authors (Curtiss and Gabrosek) found that by having a positive attitude, clearly indicating the textbook sections to be covered for each class period on the board, and providing detailed handouts, most students overcame the issue of "jumping around" in the textbook. The authors (Malone, Curtiss, and Gabrosek) were liberal in their use of handouts when teaching using the traditional sequence (see Table 1). Switching to an alternate sequence (see Table 2 or Table 3) required a simple re-ordering and editing of these existing handouts. However, it is imperative that course materials have sufficient detail so that students can follow the logical progression of content. Fewer than a dozen students out of roughly 500 have commented on having difficulty following course topics without a supporting text.

One concern expressed by some faculty with an alternate sequence was placing one-sample categorical data before one-sample quantitative data. The advantage of doing one-sample categorical data as the first case instead of one-sample quantitative data is that statistical inference is introduced earlier in the semester because there are fewer numerical and graphical summaries for one-sample categorical data than there are for one-sample quantitative data. Placing categorical data first permitted instructors to include statistical inference on the first of three semester exams. If this sequence is followed, then the instructor must introduce the sampling distribution for a sample proportion before a thorough discussion of histograms, means, standard deviations, and the normal distribution. Introducing the bell-shaped curve as an approximation to the sampling distribution of a proportion may not completely satisfy faculty, but students seem to have no trouble accepting the approximation and properties of the normal distribution. The authors found that the use of activities or simulations helped students see the bell-shaped curve as a reasonable approximation to the sampling distribution of the sample proportion.

Cobb and Moore (1997) argued that data analysis should precede data collection which serves as the bridge to inference. They suggested that the introductory statistics course should begin with exploratory data analysis (EDA) for three reasons: (1) EDA is more concrete than data production, (2) students are able to do basic EDA which builds confidence and establishes good habits, and (3) beginning with EDA prepares students for design and inference. In a traditional sequence of topics (see Table 1) all of the EDA procedures are discussed together at the beginning of the course; however, this is not the case with the alternative sequence. The EDA procedures specific to that case are discussed immediately before discussion of the appropriate sampling distribution and inferential procedures. The authors caution against placing certain data production issues, such as blocking or confounding, within a particular case as this might lead to students believing that these issues are connected to that particular case. For example, if confounding were introduced with the one quantitative variable case, then many students would incorrectly believe that confounding is only an issue with quantitative data. This problem may be avoided by introducing some of the data production issues near the beginning of the course. Such issues could and should be reiterated as they appear within the context of specific cases.

Cobb and Moore (1997, p. 803) wrote, "In data analysis, context provides meaning." We agree wholeheartedly and believe the alternate sequence provides a mechanism for the context to be present throughout the entire process—from research question to final conclusion. The entire process (e.g., posing of research question, data production, exploratory data analysis, sampling distribution, and statistical inference) is taught consecutively in time. Students are not required to recall an exploratory data analysis technique introduced in the fourth week of the semester for a particular method of data production when applying an inference procedure introduced in the tenth week of the semester. Lastly, though we agree that students find they can do EDA more easily than data production, we do not necessarily see the dividends of the claimed development of good habits when applied to statistical inference. Instead, we have found that students who performed well early in the course when the focus was on EDA can be caught off guard when the onslaught of inferential techniques begins mid-semester. We have found our students are better served by seeing data production, data analysis, and statistical inference done within a specific case repeatedly throughout the semester in various contexts.

The feedback from colleagues who have switched to an alternate sequence has been overwhelmingly positive. Colleagues have commented on an apparent increase in the students’ ability to correctly identify and carry out the appropriate analysis for a given problem. The authors have some evidence of the success of the alternate sequence on student ability to correctly identify the appropriate statistical technique for a given situation. The author (Curtiss) collected outcomes from six common exam questions in which students were required to identify the appropriate hypothesis testing technique for a given situation. Data were collected for the two semesters immediately preceding her switch to the alternative sequence of topics and for the first three semesters after the switch to the alternative sequence (see Table 3). Table 5 shows the distribution of correct responses for the six exam questions. There is an increase in the percentage of correct responses. For example, the percentage of students who correctly identified four or more scenarios was 77% for the traditional sequence, 78% for the first semester after making the switch, and 93% for the second and third semesters after making the switch to the alternative sequence. We anticipate that other instructors may also observe only marginal increases after one semester as reordering topics is a substantial change. Instructors should not get discouraged and revert back to the traditional sequence in haste.

Others have considered what to teach, how to teach, and how to assess. We have considered when to teach material in an introductory applied statistics course. Each instructor should carefully consider whether an alternate sequence is suitable for her course. For example, courses with multiple sections with common exams would have to be taught using a similar sequence. The authors have used an alternative sequence for more than three years now. Malone has taught introductory applied statistics at WSU using the alternate sequence (see Table 2) to a
Table 5. Student scores for correctly identifying inferential procedures.

<table>
<thead>
<tr>
<th>Number correct</th>
<th>Traditional sequence (W05, F05)</th>
<th>First semester, alternative sequence (W06)</th>
<th>Second and third semester, alternative sequence (F07, W08)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4 (2.3%)</td>
<td>2 (1.9%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>1</td>
<td>4 (2.3%)</td>
<td>4 (3.8%)</td>
<td>2 (1.9%)</td>
</tr>
<tr>
<td>2</td>
<td>12 (7.0%)</td>
<td>8 (7.7%)</td>
<td>1 (0.9%)</td>
</tr>
<tr>
<td>3</td>
<td>19 (11.1%)</td>
<td>9 (8.6%)</td>
<td>5 (4.7%)</td>
</tr>
<tr>
<td>4</td>
<td>27 (15.8%)</td>
<td>17 (16.3%)</td>
<td>12 (11.2%)</td>
</tr>
<tr>
<td>5</td>
<td>59 (34.5%)</td>
<td>12 (11.5%)</td>
<td>33 (30.8%)</td>
</tr>
<tr>
<td>6</td>
<td>46 (26.9%)</td>
<td>52 (50%)</td>
<td>54 (50.5%)</td>
</tr>
<tr>
<td>Mean</td>
<td>4.47</td>
<td>4.37</td>
<td>5.20</td>
</tr>
</tbody>
</table>

NOTE: Curtiss collected outcomes from six common exam questions in which students were required to identify the appropriate hypothesis testing technique for a given situation. Data were collected for two semesters immediately preceding the switch to the alternative sequence and for the first three semesters after the switch to the alternative sequence. The distribution of correct responses is presented in this table.

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