Enhancing An Undergraduate Business Statistics Course: Linking Teaching And Learning With Assessment Issues

James W. Fairfield-Sonn, University of Hartford, USA
Bharat Kolluri, University of Hartford, USA
Annette Rogers, University of Hartford, USA
Rao Singamsetti, University of Hartford, USA

ABSTRACT

This paper examines several ways in which teaching effectiveness and student learning in an undergraduate Business Statistics course can be enhanced. First, we review some key concepts in Business Statistics that are often challenging to teach and show how using real data sets assist students in developing deeper understanding of the concepts. Second, the paper examines some ways that typical learning issues faced by students taking such a course can be effectively addressed. Third, the paper describes how assessing what knowledge of statistics is retained after formal coursework is completed can provide both a rich source of feedback to improve Business Statistics courses themselves and to strengthen undergraduate business programs, in general.

Keywords: Sampling distribution, confidence interval, null vs. alternative hypotheses, short-term learning, long-term learning, first-level assessment, second-level assessment, formative assessment, summative assessment

INTRODUCTION

This paper examines several key interrelated issues commonly associated with teaching, learning and assessing student progress in an undergraduate Business Statistics course. One of these issues is that in teaching Business Statistics, Instructors often rely too heavily on artificial data to generate results which, in turn, are hard for students to interpret and understand. Second, Instructors do not take sufficient advantage of ways to enhance learning by employing a variety of classroom tools and techniques. Third, too often the assessment of learning is primarily focused on short-term retention rather than on short- and long-term retention of knowledge.

In Section I we present some key concepts in Business Statistics and illustrate how real data can make it easier for students to interpret the solutions. Section II presents some ideas on engaging ways to deal with the learning issues of typical undergraduate students. The value of conducting both short-term and long-term assessments is discussed in Section III. Section IV provides a conclusion.

SECTION I

Teaching Issues

In Business Statistics courses more emphasis is often placed on using formulae to teach concepts than on working through practical applications in areas such as accounting, finance, and operations management, where these concepts can be valuable as a means of providing useful business insights (Singamsetti, 2007). One of the reasons why this happens is because recent developments in software as well as hardware computer technology make it relatively easy for Instructors to demonstrate mathematical expressions and other functional relationships to illustrate concepts. For example, a variety of probabilities, random samples from different populations through simulations, the construction of confidence intervals, hypothesis formulation and testing, and the results of correlation and regression analysis can be instantly provided through the use of many statistical software packages available today. Given that students in a Business Statistics course have to not only understand key statistical concepts, but also apply them with proper rigor and relevance in analyzing practical data and draw appropriate inferences (Becker and Green, 2001), how we teach Business Statistics makes a real difference on the extent of student learning upon completion of the course. Below, we discuss some key concepts in Business Statistics that students often find difficult to grasp and then illustrate how using real as opposed to artificial data can help students to more readily grasp the concepts.

Sampling distribution and confidence intervals: Students are often confused between the functions of ***sample values (statistics)*** and ***parameters (constants)*** of a population. For example, the difference between a sample mean $\bar{X}$, which is a statistic, versus a population mean, μ, that is a parameter, is often difficult for students to understand as is the fact that many samples of equal size and their means constitute a sampling distribution around the unique population mean μ. Moreover, students frequently find it difficult to understand that a confidence interval, with a given level of confidence coefficient, is estimated from a sample for a parameter of the population.
Students erroneously think that the confidence coefficient of say, 95%, means the probability that the population parameter lies within the lower and upper limits computed from the sample values. The correct interpretation is that the population parameter is an unknown constant (i.e., not random) and that the interval constructed from a sample is random. In other words, because the lower and upper limits are computed from a sample, the interval can change from sample to sample of the same size drawn from a given population. Therefore, some intervals include the parameter and some do not. The confidence coefficient of 95%, therefore, represents the proportion of intervals that include the parameter in repeated sampling from the population when intervals are constructed following a certain procedure. The example below illustrates the computation and interpretation of a 95% confidence interval using real data on salaries of 856 Major League Baseball players in 2008.

Table 1 below presents a sub-set of all the salaries considered.

Table 1

Arizona Diamondbacks	Robby Hammock	Catcher	$409,500
Arizona Diamondbacks	Brandon Medders	Pitcher	$409,500
Arizona Diamondbacks	Edgar G. Gonzalez	Pitcher	$411,000
Arizona Diamondbacks	Conor Jackson	First Base	$419,500
Arizona Diamondbacks	Augie Ojeda	Shortstop	$550,000
Arizona Diamondbacks	Chris Burke	Outfielder	$955,000
Arizona Diamondbacks	Chad Qualls	Pitcher	$1,312,500
Arizona Diamondbacks	Stephen Drew	Shortstop	$1,500,000
Arizona Diamondbacks	Chris Snyder	Catcher	$1,875,000
Arizona Diamondbacks	Juan Cruz	Pitcher	$1,937,500
Arizona Diamondbacks	Brandon Lyon	Pitcher	$3,125,000
Arizona Diamondbacks	Chad Tracy	Third Base	$4,000,000

http://www.cbssports.com/mlb/salaries

Here, forty random samples of size 30 are considered from the population of 856 salaries of MLB players and 95% confidence intervals are constructed for each of the forty samples. Separately, the mean salary of the population of players was computed and found to be $3,126,149. Next, we verified whether these 95% confidence intervals include this population mean value or not. From our calculations, we find that out of forty, only three did not contain the population mean of $3,126,149. That is to say, 37 out of 40, or 92.5% of the confidence intervals computed contained the population mean and 7.5% did not. Incidentally, it should be emphasized to students that if the procedure is repeated a sufficiently large number of times, instead of just 40 as above, we actually find that 95% of the intervals do include the population mean instead of only 92.5%.

Hypotheses testing: Another area where students experience difficulty is in setting up ***null*** and ***alternative hypotheses***. In hypothesis testing, the first step is knowing what you want to test with regards to the parameters of the population. Usually, a claim made about the population parameter is considered as a null hypothesis and it always includes equality. The word null, here implies that there is no difference between the stated value and the true value of the population parameter. Some designate the stated value as the null hypothesis until shown otherwise based on some well defined statistical procedure. It should be noted, however, that the null hypothesis can also be tested against a two-sided (≠) or one sided (>, <) alternatives.

Sometimes when the claim is not evident, students get confused as to how to set up the null and alternative hypotheses. In such circumstances, as a rule, one should set up the alternative hypothesis first as 'what you want to show' (i.e., proposition to be established) based on theory and other pertinent information and opposite to this is the null hypothesis. When the alternative is <, the rejection region is on the left extreme, when the alternative is >, the rejection region is on the right extreme and when the alternative is ≠ the rejection region is located equally on both extremes. Thus, the rejection region is the set of values of the sampling distribution that is not consistent with the null hypothesis.

Students also find it difficult to understand the ***decision rule*** using more than one method to arrive at a decision. For example, in the critical value method, a computed test statistic is compared with the critical value obtained from tables using the given level of significance (i.e., alpha). On the other hand, in the p-value method the p-value (i.e., the probability of getting an absolute value of the statistic computed from the sample or a higher value) is compared with alpha. Both the methods should lead to the same conclusion or decision in testing the hypothesis.
An example of testing a hypothesis using Excel and real data is provided below.

Hypothesis Statement: The female unemployment rate is significantly higher than the male unemployment rate due to child bearing and other family obligations.

Table 2 below presents an illustrative set of real data on male and female unemployment rates (%) in U.S.A

Table 2

Year	Male	Female
1996	5.4	5.4
1997	4.9	5.0
1998	4.4	4.6
1999	4.1	4.3
2000	3.9	4.1
2001	4.8	4.7
2002	5.9	5.6
2003	6.3	5.7
2004	5.6	5.4
2005	5.1	5.1
2006	4.6	4.6

Source Department of Labor: Bureau of Labor Statistics

Working with more extensive data from 1960 to 2006 a simple t-test based on the computer results (see Table 3) provides some useful information about market conditions.

Table 3
Two-Sample t-test Assuming Unequal Variances

	Male unemployment	*Female unemployment*
Mean	5.669565217	6.291304348
Variance	2.508386473	1.735478261
Observations	46	46
Df	87	
t Stat	-2.046945835	
P(T<=t) one-tail	0.021840381	
t Critical one-tail	2.369976746	

We illustrate the testing procedure below.

μ_1: Unemployment mean for male population
μ_2: Unemployment mean for female population

Then:

$H_{o\ (\text{Null hypothesis})}$: $\mu_1 - \mu_2 \geq 0$
$H_{a\ (\text{Alternative hypothesis})}$: $\mu_1 - \mu_2 < 0$

Critical Value Method assuming α =0.01

The value of the t-statistic from the printout is t = - 2.05
t critical value for one tail = - 2.37

Decision rule: Reject H_o if computed t < - 2.37

In this case: - 2.37 < - 2.05 and thus we fail to reject H_o.

Conclusion: Contrary to general perception, the female unemployment rate is not significantly higher than the male unemployment rate.

P-Value Method:

We derive the same conclusion as above with the P-Value Method because the p- value from the print out 0.02 is higher than the level of significance 0.01.

However, using the above example, we come to an opposite conclusion in this case if we use α =0.05 by either method. This suggests that the hypothesis has to be re-examined with multiple assumptions and possibly more data to see if the conclusion(s) continues to be supported.

Correlation: Usually this is one of the final topics that is covered in an undergraduate Business Statistics course. A correlation coefficient is defined between two variables, say X and Y. This relationship has two important aspects that students need to clearly understand. The first one is the ***sign*** that indicates the nature of the relationship. A positive sign indicates a direct relationship and a negative sign indicates inverse relationship between the two variables. The second aspect of the correlation coefficient is the numeric value indicating the ***strength of a linear relationship*** between the two variables on a scale of 0 to 1. A value of zero represents the absence of linearity and the value of one represents perfect linearity.

The most challenging idea for students to understand here is that the statistical independence of two variables implies a zero correlation, but the converse is not true. In addition, if all the points in the scatter diagram lie on a straight line parallel to either X (Y is constant) or Y (X is constant) axis, the correlation coefficient is undefined since the formula assumes 0/0 indicating there are no two variables. Furthermore, the correlation coefficient is symmetric between X and Y in the sense that it does not recognize a cause and effect relationship between the two variables. This kind of rigorous type of discussion of correlation coefficient is often absent in many text books on Business Statistics as are practical examples.

Here real data can again be helpful in demonstrating important concepts to students. As an example, consider three variables, the Rate of Return on Standard & Poor 500 Index (**STR**), the DOW Jones Corporate Bond Rate of Return (**RCB**) and the 90-DayTreasury Bill yield (**RTB**) for a thirty year period computed from Global Financial Data for 1978-2008. For illustrative purposes, a portion of the data on these variables is presented in Table 4 below.

Table 4

Date	STR	RCB	RTB
12/31/1998	28.58%	10.26%	4.37%
12/31/1999	21.04%	-2.85%	5.17%
12/29/2000	-9.10%	9.41%	5.73%
12/31/2001	-11.89%	10.73%	1.71%
12/31/2002	-22.10%	11.14%	1.20%
12/31/2003	28.68%	10.02%	0.93%
12/31/2004	10.88%	6.25%	2.18%
12/30/2005	4.91%	1.40%	3.99%
12/29/2006	15.80%	3.70%	4.89%
12/31/2007	5.49%	5.24%	3.29%
12/31/2008	-37.00%	1.80%	0.11%

Source: www.GlobalFinancialData.com. **STR** : S & P 500 Index Return , **RCB**: Dow Jones Corporate Bond Return and **RTB**: 90-day Treasury Bill Yield.

Excel software was used to produce the following matrix displaying the correlation coefficients between the three variables.

Table 5

Correlation Matrix.

	STR	*RCB*	*RTB*
STR	1		
RCB	0.303986	1	
RTB	0.354671	-0.06392	1

From the above correlation matrix in Table 5, it can be seen that the correlation coefficients between any two variables are presented only in the lower triangle and the correlation coefficients in the upper triangle are not presented because they are symmetric. (i.e., the correlation coefficient between **RCB** and **STR**, 0.303986, is the same as the correlation coefficient between **STR** and **RCB.)** The 1's in the diagonal indicate the correlation coefficient of the variable to itself. Positive values indicate direct relationship and negative values indicate an inverse relationship between the variables. It is worth repeating, however, that the correlation coefficients do not indicate any causal relationships between any of the two variables.

Regression: Regression analysis, discussed below, is an improvement over correlation analysis as it requires the specification of the variables as independent or dependent and provides the possibility of showing a causal relationship which is crucial in the evaluation of programs and policies including forecasting. Here students need to recognize that regression analysis examines the relationship between the conditional mean of the dependent variable for given values of non-random independent variable(s). If this functional relationship is linear, then it is known as linear regression. Otherwise, it can be described as a non-linear regression relationship.

Returning to our earlier discussion, the correlation coefficient gives the direction and strength of a linear relationship, but it does not indicate a causal relationship between the two variables because it is symmetric. On the other hand, regression describes a specific cause (X) and effect (Y) relationship. This is extremely useful in estimating the marginal effects of given changes in X-values on the estimated mean of the dependent variable. Moreover, the regression equation can be used for forecasting or prediction purposes. Thus regression is an improvement over correlation.

Before leaving this discussion, it needs to be noted, however, that it is extremely important to identify the dependent versus independent variables based on theory and other means before specifying a regression relationship. For example, identifying a dependent variable versus independent variables is a common issue in applications. The example below presents the p-value indicating the significance of the regression relationship as a whole when different dependent variables are selected.

Here we considered two regression models, one with RCB as the dependent variable and the second with STR as the dependent variable. Then, using Excel software we computed regression on the other two explanatory variables. The regression results are presented in Table 6 below.

Table 6
Regression Results

Dependent Variable	Independent Variables	(P-value)
RCB	STR, RTB	0.1514
STR	RCB, RTB	0.0244*

*Significant at 5%

The p-values of the above regressions with different dependent variables to be explained clearly suggest opposite conclusions on the statistical significance of the regression models. Obviously, the first model is not significant with a p-value of 15.14%, whereas the second model is highly significant with a p-value of 2.44%. Thus, this example demonstrates the need for the student to choose the appropriate dependent variable based on economic and financial theories as well as experiences of professionals when examining potential cause and effect relationships.

SECTION II

Learning Issues

To teach Business Statistics effectively, the Instructor must take a number of short- and long-term learning issues into consideration. For example, in the classroom Instructors need to take into account the variety of academic backgrounds of students coming into the course. Among other things, this means understanding what level of knowledge and skills students have developed in previous courses in mathematics, their knowledge of excel as well as writing, communication and other skills. In addition, the Instructor has to continuously monitor the engagement and interest of the students in the subject matter throughout the course.

When dealing with general issues such as the range of ability and interest in the course material, it is possible to promote more short-term learning by using traditional approaches such as: group assignments; student class presentations; occasional quizzes; and having the Instructor accessible for out-of-class consultation and guidance. The Instructor can also enhance short-term learning by integrating technology throughout the course through a variety of means, such as power point presentations, the use of electronic Blackboard, and the internet to access databases.

If the goal of the Instructor, however, is to reduce the wide variation of ***all*** the students' performance in the class and enhance the general level of knowledge rather than, for instance, just teaching to the middle range of students additional steps need to be taken. For example one way to pursue this goal is by designing customized group assignments to enhance the learning of both the lower-end and higher-end performing students. Such well defined joint projects will, obviously, benefit low performing students by providing them with peer coaching. It also benefits high performing students by promoting self confidence, communication skills, self-esteem and leadership abilities. Incidentally, mid-range students also benefit from not being slowed down by the low-performing students.

Short-Term Learning. During the semester, students are continuously processing information from multiple courses at the same time and selecting information from each course to store in short-term memory for near term retrieval. According to Erickson, Peters and Strommer , 2006, students naturally select pieces of information that make sense to them, are interesting to them, and appear relevant in understanding concepts being studied that may be required for later recall. In addition, it needs to be noted that new information is constantly being processed by students, causing unused information to be stored further from instant recall or lost altogether. Moreover, the longer the interval between storing information for short-term recall and using it, the greater the chance that unused information will dissipate to free storage space for new information. Knowing this, Instructors can help students retain knowledge by connecting the concepts to situations and experiences that are of immediate interest to the student and that will be used in future business courses as well as at work.

More precisely, if students see why the course is relevant to their overall business studies, they will be motivated to learn the material more quickly and retain the knowledge longer. Therefore, it is essential to bring to the attention of students in the class, the latest and most appropriate information on businesses through publications such as the *Wall Street Journal, Business Week, Barron's* and other business magazines. To further sustain students' interest, Instructors need to integrate current business developments with the use of statistical techniques, employing appropriate software such as excel and a variety of historical data sets. Another way an Instructor can impress upon the students the relevance of the course material is by directly linking the variety of topics presented in the class to real world situations. For example, the use of mean versus median salaries, standard deviation as a measure of market fluctuations (risk), weighted means (averages) like the Consumer Price Index, the Standard and Poor's 500 index, and student's grade point average can be emphasized in introducing numerical measures in the topic of data analysis. Yet another approach to enhance student learning is to present some games of chance such as casino gambling and government approved lotteries. For instance, students are often interested in finding the probability of obtaining a sum of 7 in rolling two dice once. Likewise, the probability distribution of cash prizes in a power ball lottery attracts students' attention. These games assist students in making connections between entertainment and statistics and thus promote short-term memory (Erickson, et. al., 2006). In other words, enhancing students' learning capability by anchoring concepts to interesting and fun activities assists in the strengthening of memory for the student and provides the basis to recall the subject at later times.

Long-Term Learning. Advanced business courses build on prior learning, which includes statistical concepts, thereby creating the need for retention of learning through long-term memory recall. Long-term memory contains information that is anchored utilizing both surface and deep processing techniques (Erickson, et. al., 2006). These anchors assist students in recalling information particularly when the anchor is familiar to the student. In addition, anchoring concepts aids the student in categorizing information in their long-term memory.

In the case of business students, they particularly like to see how concepts and statistical analyses are linked to every day business applications. Accordingly, when dealing with topics like statistical inference, students appreciate the introduction of examples such as control charts and forecasts on a variety of things including election results and Nielsen's T.V. Program ratings as well as the application of six-sigma tools and techniques that are commonly used in business to improve the quality of products (e.g., reducing defects) and services (e.g., better surgical procedures).

In other words, examining everyday applications with the aid of statistical methods promotes what is known as "surface processing". Surface processing is critical for long-term memory because anchoring information to concepts promotes recall at a later time (Erickson, et. al., 2006). That is to say, short-term memory is useful when memorizing information for an immediate quiz or examination, but long-term memory helps recall the information for use in a subsequent course and future business situations. For example, surface processing allows the student to recall a particular concept at a future time based on the anchor, such as the earlier example for the computation and interpretation of a 95% confidence interval using real data on salaries of 856 Major League Baseball Players in 2008. These salaries form the "anchor" for the selection of a sample and the 95% confidence interval is the "concept" including the computation and interpretation. Likewise, the use of regression analysis to study "cause and effect" relationships, in general, requires short-term memory recall, whereas exploring "cause and effect" of things that undergraduate students can readily relate to like meal plan choices and their housing selection promotes long-term memory recall.

Another good way to promote effective long-term learning is to give students an opportunity to formulate a question and answer it in their own words on any concept or topic covered in the class. Indeed, formulating questions and answering them, is one of the best ways to promote "deep processing" of information. Deep processing is defined as the ability to understand and anchor new concepts to a variety of experiences (Erickson, et. al., 2006). Students utilize deep processing as they develop understanding of the new concepts or when examining existing information in new ways. For example, students formulating questions after setting up their *null* and *alternative hypotheses* from a variety of their personal experiences helps them and other members of the class as they relate the concept to their own experiences and those of others.

SECTION III

Assessment Issues

First-level assessment. When undergraduate students take a Business Statistics course their level of knowledge is typically assessed throughout the course of study by traditional examinations and quizzes utilizing "formative" and "summative" assessments. Formative and summative assessments are useful as they help the Instructor determine the level of knowledge retained in the short-term and provides the potential to adjust teaching methods as needed. These assessments are important and routinely done. In view of the fact that these assessments are usually conducted while the material is being taught, it can be considered to be a "first-level" assessment.

More precisely, formative assessment is best described as an "in the moment" assessment providing real time information for the Instructor to adjust the instruction to address learning gaps for the benefit of the students (Wiliam, 2006). For example, when an Instructor gives students an opportunity to formulate a question and answer in their own words, it provides an "in the moment" assessment of the students' understanding of the material covered. At this point the Instructor has the opportunity to reframe or expand the instruction to encourage more learning. Thus formative assessment benefits both the students and also assists the Instructor in refining the presentation of the course material (Wiliam, 2006).

Meanwhile, summative assessments may be described as the outcome of the Learner-Instructor process recorded as grades indicating student performance relative to the course objectives (Ali and Ho, 2007). Summative assessments evaluate both short-term memory recall and surface processing. The results benefit Instructors as a feedback mechanism assisting in understanding the strengths of the course and giving insights into possible opportunities for improvement in teaching based on observed learning.

In addition to the traditional first-level assessment methods noted above, member institutions of AACSB (Association to Advance Collegiate Schools of Business) International are required to develop Assurance of Learning (AoL) goals for the institution. Assurance of Learning (AoL) as defined by AACSB International is a "measure of direct educational achievement" and provides the means to determine the degree to which goals identified by the institution are actually being achieved by the students (Martell, 2007). Assessment measures are generally conducted for a particular goal in the degree program based on the work of a sub-group of students and the results are analyzed to determine if the goal(s) was met. Based on this assessment, process improvements may be proposed in an effort to further promote student achievement in future courses.

Second-level assessment. Second level assessment is an extension of the AoL standards and can further enhance the assessment process. This step measures "retained knowledge" required in a particular field of study such as Statistics or Operations Management and also provides the Instructor with both the ability to benefit the "current student" as well as identify improvement areas for prior steps in the learning process. This additional level of assessment adds to the continuous process of understanding and refining learning goals to improve the overall degree program.

For students pursuing an undergraduate degree in business, developing knowledge of Business Statistics, for example, is not only important while taking a statistics course(s), but ***retaining*** this knowledge is equally important as it can influence how well they will do in a number of upper-level business courses such as Operations Management and Finance (Martell, 2007). Thus, conducting an assessment of the amount of retained knowledge can be considered to be a "second level" assessment. While this type of assessment is also important, it is less commonly conducted. Below, we will discuss a number of ways in which this type of assessment can provide valuable information to Business Statistics Faculty and Administrators that is not available through first-level assessments alone.

As we have discussed, Instructors utilize various teaching techniques and learning strategies to assist students with anchoring information to aid deep learning. A second level assessment provides the opportunity to insure the techniques worked and students are retaining knowledge based on those strategies. Upon discovery of deficiencies in the level of retained knowledge, Instructors may elect to use class time to revisit previous learning strategies. This can be accomplished by reviewing teaching techniques that were used initially to anchor concepts in an effort to refresh the deep processing of long term memory. In addition, it may be helpful to encourage students to utilize existing statistics tutoring labs. In the event the student has not developed sufficient deep learning of statistics, a mini refresher workshop may be recommended or required. The workshop could be an accelerated process focusing on concepts utilizing surface and deep processing techniques and scheduled for the first several weeks of class. Another approach to aid student learning and retention is providing a tutoring lab for the current subject, with special emphasis on the statistics knowledge required to succeed in the course.

A second-level assessment of retained knowledge can, therefore, open many avenues for improving teaching and learning in specific courses and to enhance the overall structure of a business degree program. Three illustrative ways that the measurement of retained knowledge can be helpful are discussed below (see Figure 1).

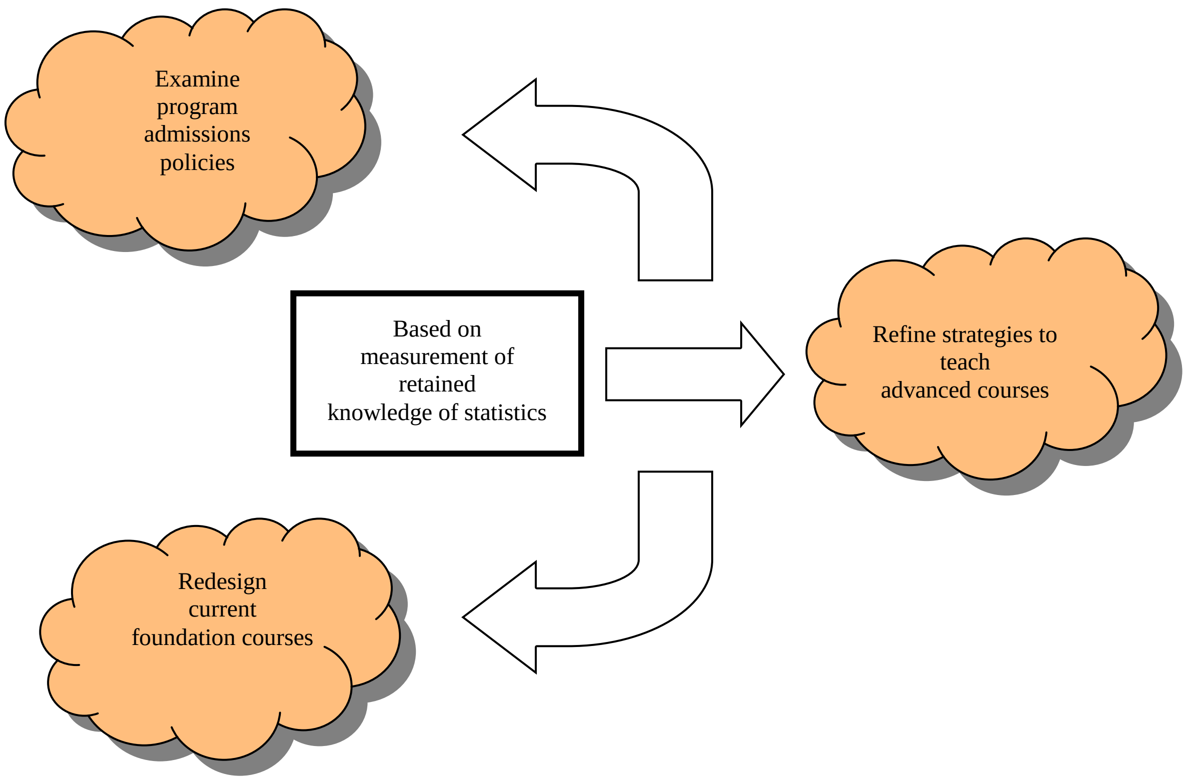

Figure 1

- To provide Instructors in upper-level courses with general information on the statistics background of their new students to refine their teaching strategies.

Consider the following experiment undertaken by the Statistics faculty of our Business School. Over the years, faculty teaching Operations Management and Finance in our business program have expressed concern that there was too much variation in the knowledge of statistics among the students coming into their classes. Responding to this concern, our Statistics Faculty recently created a 30-item diagnostic test of general knowledge of statistics to be administered at the start of our junior-level Operations Management course. This multiple-choice diagnostic test, which is administered during the first two weeks of our Operations Management courses is comprehensive yet only takes thirty minutes to complete. Students are not given any advance notice of this test nor are their test scores factored into their grade in the course. The below frequency Table 7 displays the overall performance of fifty-five students during the first administration of the diagnostic test.

Table 7

Number of questions answered correctly	1-5	6-10	11-15	16-20	21-25	26-30
Number of students	1	14	29	10	1	0

Table 7 shows that there is a relatively normal, although somewhat skewed to the right, distribution of retained knowledge of statistics among the students who were starting to take their Operations Management course. Accordingly, the Instructors would need to use a variety of ways, several discussed earlier, to optimize the learning of all the students taking the course.

- To examine if admission policies relate to current levels of retained knowledge.

Working with the data obtained from the diagnostic test, we pushed our analysis deeper by examining if our admission policies are related to the observed levels of retained knowledge. In this case, our students entering the Operations Management course came through three different routes. Specifically, these students came from: the Business School and other 4-year programs at the University (G1); transferred into the Business School from outside of the University (G2); or came from a large 2-year feeder program (G3). Working with these three identity groups, we conducted tests of several propositions to gain greater insights into the relationships among and between the scores of the three groups.

Proposition 1. Student performance in the diagnostic test is independent of where they took their previous course(s) in statistics. Table 8 below shows two levels of test scores (i.e., 50% or less correct and more than 50% correct) observed among the three groups of students and the p-value of the Chi-square test for independence.

Table 8
Chi square test for independence among student groups and test score levels.
Observed frequency of students with two levels of test scores.

Student Groups	50% or less correct	More than 50% correct	Total	P-value of Chi-Square
G1	18	7	25	**0.0143**
G2	6	4	10	
G3	20	0	20	
Total	44	11	55	

It is evident from the p-value (1.4 %< 5%) in Table 8 above that performance is dependent on where the students received their prior statistics training.

Propositions 2, 3 and 4. We next tested the equality of mean scores between any two groups of underlying populations. Specifically, we conducted t-tests for the equality of means between G1 and G2 (proposition 2), G1 and G3 (proposition 3) and G2 and G3 (proposition 4). Table 9 below shows the test results of propositions 2, 3 and 4.

Table 9
Results of t-Test for equality of Means:
Two-Sample Assuming Unequal Variances.

Mean scores	G1	G2	p-value one tail
	13.24	14.60	0.18
Mean scores	G1	G3	p-value one tail
	13.24	10.4	0.00*
Mean scores	G2	G3	p-value one tail
	14.60	10.40	0.01*

* Significant at 1%.

From Table 9 above, based on the p-value of 18% for proposition 2, we conclude that there is no significant difference between the mean scores of G1 and G2 groups of student populations. However, with regard to proposition 3, based on the p-value of approximately zero for one tail, one can see that the mean score of the G1 student population is significantly higher than the mean score of the G 3 student population. Similarly, with regard to proposition 4, the p-value of 1% indicates that the mean score of the G2 student population is significantly higher than the mean score of the G3 student population.

Thus, based on the test results presented above on the four propositions, we conclude that the overall student performance in the diagnostic test depends significantly on where these students took their previous statistics course(s). This shows how important admission policies might be in influencing the composition of a class. Armed with this insight, there are several steps that can be taken. One way is to schedule multiple sections of a Business Statistics course and the registration of students into these sections from these three different groups. For example, special sections can be designated for the relatively low performing students from the G3 population. Alternatively, the Instructors have to be aware of the mix of students in these classes coming from different colleges and adopt various pedagogical techniques such as cooperative group learning suggested in Section III above to help reduce the variation and at the same time enhance the student performance levels.

- To understand the current strengths and weaknesses of foundation course offerings.

It is obvious that the conclusions reached above on the four propositions are based on the assumption that the diagnostic test is fair and balanced. Therefore, as part of the overall assessment process, it is essential to establish that the diagnostic test itself is proper and appropriate for all the populations, and if necessary, to revise the test. To accomplish this, as part of the assessment process, the faculty that teach multiple sections of Business Statistics met twice and discussed a variety of issues related to the diagnostic test. Based on this review a refined diagnostic test has emerged. So, the cycle of continuous improvement continues.

SECTION IV

Conclusion

Instructors should always be conscious of the fact that teaching, learning, and assessment issues_are intertwined and each can be used to enhance the long-term acquisition of knowledge. In this paper we illustrated a number of ways to improve the quality of teaching, learning, and assessment of *retained knowledge* acquired in a typical undergraduate Business Statistics course. To do this we first presented several key statistical concepts, interpreted the results of some analyses, and showed how using real data can help students to more readily understand these concepts. Next, we discussed a number of teaching strategies that can enhance both short-term and long-term learning. Then, we discussed the differences between first-level and second-level assessments and demonstrated how the assessment of retained knowledge, in particular, can: aid Instructors teachings advanced business courses; to gain greater insights into the impact of admissions policies on class composition; and how this type of assessment can be used to improve the structure and content of foundation statistics courses.

AUTHOR INFORMATION

James W. Fairfield-Sonn is the Dean and a tenured Professor of Management at the Barney School of Business at the University of Hartford. His research interests center on understanding how corporate culture and quality practices influence organizational performance. In addition to lecturing throughout the United States and Europe on these topics, he has also published his findings in many journals and authored a book on the subject entitled, *Corporate Culture and the Quality Organization*.

Bharat R. Kolluri is Professor and Chair of the Department of Economics, Finance, and Insurance at the University of Hartford. His articles have appeared in journals such as *Journal of Macroeconomics, The Southern Economic Journal, and The Review of Economics and Statistics*. He presented papers in a number of professional organizations including Financial Management Association, and International Symposium on Forecasting. His current research activity deals with public expenditure growth, common stock returns and the expected rate of inflation.

Annette Rogers is Assistant Dean at the University of Hartford, Barney School of Business. She is currently a Doctoral Candidate in the College of Education, Department of Educational Leadership at the University of Hartford.

Rao Singamsetti is an Associate Professor of Economics in the department of Economics, Finance and Insurance of the AACSB-International accredited Barney School of Business at the University of Hartford. His articles have appeared in the *Journal of Productivity Analysis, Journal of Statistical Planning and Inference, Southern Economic Journal* and the *International Journal of Industrial Organization*.

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