BUILDING BRIDGES IN EXPERIENTIAL STATISTICS

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ABSTRACT

Clearly defined learning objectives precede the teaching of any course. This paper introduces a three dimensional objectives matrix and proposes pedagogy for attaining the goals of the matrix. The y axis shows Bloom's taxonomy with rote memorization near the origin and critical thinking skills at the top. The x axis shows Daggett's topic relevancy with "can be applied in the course being taught" at the origin, progresses through "can be applied in other courses" to "can be applied in the workplace." The z axis shows retention over time, progressing from "short term memory" through "working memory," to "long term memory." The conclusion is made that, by default, too many courses are centered near the origin of this matrix whereas employers need workers skilled at the outer region of the matrix. The paper discusses how this matrix is used as the focus of a business statistics course and describes three experiential learning techniques which reinforce these goals.

INTRODUCTION

Prerequisite to teaching any course is a set of well-defined learning objectives. These objectives often differ between the student and the instructor. The sole objectives in the mind of many students are to get a good grade in a course and to use the course to meet graduation requirements. Thus the imposition of larger objectives is left to the instructor.

Daggett had developed an interesting rigor/relevance framework which the author has modified into a three-dimensional Rigor/Relevance/Retention course objectives matrix for consideration (see Figure 1). The y axis shows Bloom's taxonomy, with rote memorization at the bottom of the axis and evolving to critical thinking skills at the top. Most instructors of statistics realize the possibility available in the subject matter of using the course to develop higher order thinking skills. The x axis shows subject applicability. Going from "can be applied in the course being taught" at the origin, it moves on to "can be applied in other courses in the curriculum" to "can be applied off campus in the workplace." Learning theory shows that students can place material in "short term memory," "working (medium) term memory," or "long term memory." The z axis reflects this important dimension to learning with short term memory at the origin.

Upon reflection, it will be seen that the learning objectives of too many courses occupy the space near the origin of this objectives matrix: rote memorization, for the short term, so that the student can get through the next exam in this course. It must be clear to anyone who thinks in terms of the matrix that a more useful set of objectives lie in the furthermost region: full comprehension of the material in a way that motivates clear thinking, retaining the material until after graduation, and possessing competency to apply the material wherever students find themselves after graduation.

The author focuses his entire efforts in the teaching of a two-semester sequence of statistics to moving students to the outer region of the matrix described above. The purpose of this paper is to describe how this is accomplished.

TIME

Learning theory states that humans place learned material into one of three categories: short-term memory, medium-term memory (working memory), or long-term memory. Material placed in short-term memory is available only for a matter of seconds or minutes: you look up the phone number for the pizza place and don't want to retain this information longer than it takes to place the call. Material in the medium-term memory is retained only for a few hours. Clearly, if our objective is to carry a practical competency of the subject matter into the workplace after graduation, knowledge regarding statistics must be placed in long-term memory.

To meet the time objective, students must first be made aware of the differences in kinds of memory and then told how material can be placed in long term memory. The author brings this point home forcefully in the second statistics course by giving the students a quiz the first day of class. The quiz (available on request) covers only the most fundamental basics of the statistics taught in the first course. The results are dramatic: thirty percent of the students get a zero on the quiz and the average grade is fifteen percent. Students who felt good about getting an 'A' or a 'B' in the previous course only a few months (or even weeks) before are shocked at how little material they have retained. Having thus motivated the need in the students for a more useful retention of subject matter, learning theory is explained and students are told that night-before-the-test cramming at best places subject matter in medium-term memory. Accordingly, a clear under-standing, a social contract, is reached with the students the first day of class: the students will study statistics two or three hours between each and every class period, as opposed to the more typical mode of deferring study for two or three weeks and then camming the entire weekend before the test. It is only when the material is repeatedly revisited and thought about that it can seep into long-term memory.

HIGHER ORDER THINKING SKILLS

Higher order thinking skills are developed in two ways: the bridging exercises described below, and the approach to teaching taken in the classroom.

To the maximum extent possible, students are shown in class not only the statistical methodology under study but also why the method does what it does. Students, for instance, are never taught the "finger method" of doing a chi-square test of independence: they use their understanding of categorical data and the binomial probability distribution to derive expected frequencies. Students are never taught to look at which way the inequality is pointing in the alternative hypothesis to find the rejection region: they are forced to think through the sampling distribution and which values of the sample statistic are unreasonable and thus lead to the rejection of the null hypothesis. Students must understand and be able to do analysis of variance and simple regression by hand before being allowed to go to the computer. Students are never given the sample statistics when doing an estimation or hypothesis test on an exam; they are provided with raw data from which they must first calculate statistics before they are able to make inferences. The author avoids, where possible textbooks whose end-of-chapter problems include the phrase "assuming this situation can be modeled by the xxxx distribution (or which teach the 'finger method' or 'look at the direction of the inequality');" students must be able to reason through to the appropriate distribution from the situation given, just like in the workplace. When students are given definitions they are told that they are not to memorize them and expect to give them back to the instructor on an exam (rote memorization); rather they are expected to comprehend them and to make them part of their working vocabulary. Thus every effort is made in class to move the students from memorizing, and looking for crutches, to actually understanding concepts and developing the ability to apply them to real situations.

EXPERIENTIAL BRIDGING MECHANISMS

Learning theory says that most students best understand and retain material when they actually experience it rather than being told about it (though previously lectured, the author first understood sky-diving when he stepped off the wheel of an airplane at an altitude of 1800 feet). Three different mechanisms have been attempted by the author in recent years to allow the students to actually experience statistics. All have been quite successful. Each will be described below.

Bridging exercises

It seems clear to the author that, if one really buys into the notion that a course objective should be that the student must be able to apply the subject matter outside the college
campus, the best way to develop this ability is to require the student to apply the subject matter off campus. Thus, in the second statistics course (the concept could be used also in the first course or even a high school statistics course), every student is required to complete at least two "bridging exercises."

The name for the exercises derives from the fact that the purpose of the exercise is to develop the ability to build a bridge between the course and the "outside world." The student is free to choose the topics in the course that will be bridged to the outside world. Most students at York College work at least part time and students are encouraged to apply the selected topic in their place of work. If they do not work, they are encouraged to communicate with a working parent asking them to obtain actual work data. Confidential data is easily masked by moving decimals or multiplying by a constant. As a last resort, students are permitted to gather data from their personal lives (e.g., an interval estimate on how long it takes a roommate to take a shower, or a two-way analysis of variance to determine the best route to school given alternate routes, the time of day or day of the week), though few students are forced to take this approach.

Since the skill being developed is the ability to see the relationship between subject matter and the workplace (building the bridge) students are provided no help from the instructor in building the initial bridge. After the initial idea is proposed by the student, the instructor is available as a consultant for help with the implementation. At least two bridging exercises are mandatory but the students may do as many as four. Four major exams are given in the course (three during the semester plus the final exam) and ten points are added to an exam grade for a correctly-completed bridging exercise covering the material in that exam. Students must have a bridging exercise proposal approved before the exam which covers the topic being used, but then has until the end of the semester to gather data and complete the exercise. Again as practice for the workplace, the submitted document is formal: typed and of professional quality.

The author has found that, early in the semester, students exhibit considerable anxiety and distress about being thrown on their own resources and being required to think on their own. Toward the end of the semester, on the other hand, students gain confidence in themselves and get excited about, and quite adept at, applying statistics outside the class room. End of semester comments from students typically include remarks that they feel they really understand statistics and are confident about, and look forward to, interviews with prospective employers. Graduates sometimes report that "I now see everything that goes across my desk in terms of statistics."

Poker chip exercises

The author has found it useful to subject the entire class to a common experiential exercise that can provide a common reference throughout the semester. Accordingly, eight hundred poker chips are used to represent "widgets." Specifically, the class is told that it is a subcontractor to York International Air Conditioner Company (a real employer in York, Pennsylvania). Specifically, we provide air-conditioner fan blade shafts. Since the shafts must be press fit into ball bearing sets, the shaft diameter is critical; specifically the diameter must be 0.2000 ± 0.0003 inches. The only imposition on the student's imagination is to imagine that a poker chip is one air-conditioner shaft. A number painted on each chip represents the deviation of the shaft diameter from the target value with the decimal moved four places. Thus a chip showing a plus five is five ten-thousandths on the large side. In order to expedite an order for eight hundred shafts, two hundred shafts were made on each of four machines (represented by four "tote pans" each containing 200 poker chips). The number of red dots on the back of each chip represents the machine the "shaft" was made on. Finally, the number of blue bars on the back of a chip denotes which shift the shaft was made on. The worker who runs each machine on each shift is identified and some human resource data is provided on these workers. The students are told that we have a quality problem and that each student must prepare as an end-of-semester case study, on the basis of samples taken from the four "tote pans" of shafts we have, an analysis of our process, identification of possible problems, and recommended changes which should resolve the quality problem (alternatively, the student buys steaks for a restaurant chain: each poker chip represents a purchased steak and the number on the chip represents the number of ounces the steak deviates from the desired 16 ounces).

As can be seen from the Figure 2, the shaft dimensions (or steak weight) in each set of two hundred chips are normally distributed, each having different means and standard deviations. As the exercise is introduced, a few volunteer students come to the front of the class and sort the chips from one of the chip sets according to diameter (weight). This may be the only time in their lives that the students actually see something that is normally distributed. What is normally distributed - the shafts or the shaft diameters? Thus the student is introduced to the difference between an experimental unit (an entity) and the unit's characteristic of interest. When asked to restack the chips according to whether the shaft is defective or not (i.e. whether the magnitude of the number is greater than three), the student sees the different levels of measurement available for the characteristic of interest and the profound difference between quantitative and categorical characteristics. As an out-of-class exercise each student is required to sort all four sets of chips and produce a frequency distribution table for each set. They then use the math for grouped data to calculate the mean and standard deviation of the four populations.

Each student draws samples of size five from the first population and calculates the sample mean and standard deviation. The sample means from several hundred students are collated and returned to the students. The students then produce and plot relative frequency distribution polygons from these sample means and calculate the mean and standard deviation of these sample means. This important exercise allows the student to understand, at a visceral level, the difference between the distribution of some characteristic over a population and the corresponding sampling distribution. References in class to "sigma x-bar" now have direct meaning. This process is repeated by having students draw samples and finding the sample proportion defective. The resulting hundreds of p values are returned to the student and the p sampling distribution is created. The mean and standard deviation of this p distribution is calculated as above. Samples are drawn in a similar manner from two poker chip populations and the sampling distributions for Δ x-bar and Δ p are created by the student. Throughout the semester, as these sampling distributions are used in inferential statistics, students are reminded of this exercise and what these distributions mean in terms of their own experience with them.

The sets of “shafts” (or steaks) are used throughout the course to teach almost every topic. Students draw samples to estimate (already known) population means, variances and proportions. Differences in percent defectives or population means between two populations are estimated. Hypothesis testing can be used to test assumptions regarding differences in means or proportion-defectives between two populations. Two way analysis of variance on samples tests for differences in diameters among all four machines, among the three shifts, and possible interactions between machines and shifts and thus individual workers. After completing this exercise, students are asked whether they had thought through the assumptions underlying ANOVA. The better students think to use Levine’s procedure to test for homoscedasticity. Chi square test of independence can be used to look for a relationship between defective shafts by machine and by shift.

In short, this experiential exercise not only can be used to teach many of the topics contained in the second course but, when doing any problem in the text, the student is brought back to what they know and understand by asking what a poker chip would represent in the problem under study.

Consistent with the objective of developing critical thinking skills, students are not told to use analysis of variance, chi-square, etc. in the poker-chop case study; it is their task to identify the appropriate statistical tool and at the appropriate time. Thus students again develop both the facility to think on their own and to bridge from class lectures to their application in a (simulated) workplace.

Running text case studies

The third experiential exercise is probably one used by many statistics instructors. Many statistics texts have end-of-chapter case studies. Some have running case studies: using the same companies throughout all chapters of the text. The author has found that students can approximate a real world experience by being told that they should imagine themselves as interns at one of these companies. With little or no input from the instructor, they work on each case study as the semester progresses and are required at the end of the semester to write a formal coherent and integrated “internship” report to the company management providing the insights gained from their analyses and corresponding recommendations. This “bridge” lacks the relevancy associated with applying statistics to the company where the student or their parent actually works, but it is a major improvement over the usual simple unrelated end-of-chapter problems.

FUTURE RESEARCH

In addition to providing students with a useful experience *within* their statistics sequence, the author is also concerned with breaking down the “functional silos” that exist *among* the course offerings within the business curriculum, wherein each business subject is taught as though it exists in isolation from the other business courses. Towards this end, the author is proposing that the second statistics course be coupled, and team-taught with, the required operations management course.

Operations management, as it is currently taught at York College, involves student teams that are assigned to corporate “mentors” at local manufacturing or service-sector businesses. In addition to the usual class lectures, students are provided with periodic plant tours in their assigned business and instruction by the mentor as to how principles taught in class play out in this actual company. The student teams must then prepare and present a major paper at the end of the semester describing operations management as it was used in the company observed.
The author is proposing that, as part of the student investigation of the company under study, teams identify problem areas having potential for analysis and resolution by use of statistics. Thus the structure will exist for tying the “bridging exercises” currently in place in the statistics class to the operational analysis currently being conducted in the operations management class. Mentors who are encountering actual problems within their (real) companies will be able to bring the problems to the attention of the student teams and thus gain access to the expertise of the College statistics instructors for problem resolution. The students will gain the enormous advantage of seeing the practical application of statistics in the workplace for solving real problems in addition to gaining experience in actually using statistics to solve real problems.

CONCLUSIONS

The author hopes that the course objectives outlined in the introduction seem reasonable. Indeed, they seem to have merit whatever the course being taught. The British-American philosopher Alfred North Whitehead, speaking on the need for knowledge to have relevancy, said “All ideas have relationships beyond themselves. Thus unapplied knowledge is shorn of its meaning…without our attending to its usefulness, our knowledge becomes inert, a mere burden on our memory." If the objectives are agreed to, the need for pedagogy which strives towards them becomes apparent. Faculty who are unaware of how little students retain of the topics taught are encouraged to follow example and give first-day quizzes in follow-on courses testing the retention of material retained from predecessor courses.

Student response has been remarkable. The author was concerned about the extensive amount of work imposed on the students by the poker chip exercise. Recognizing the possibility that three different bridging modalities in the same course might be excessive, and concerned with the amount of work associated with the poker chips, the author invited all sections of the class in Spring of 2003 to complain on their course evaluations about the chip exercises but then to give an honest assessment of its contribution to their understanding of statistics. The results were surprising: the students were consistent in their appreciation of the insight gained both from the poker-chip exercises and the bridging problems, but disliked the running textbook case studies. It is possible that the text case studies, if assigned by themselves and used in a different manner, may elicit a more favorable reception. They would certainly be recommended over doing no experiential exercises. Reacting to these outcomes assessments the author has decided to drop the textbook case study exercises while retaining the other two types of experiential learning in the near term.

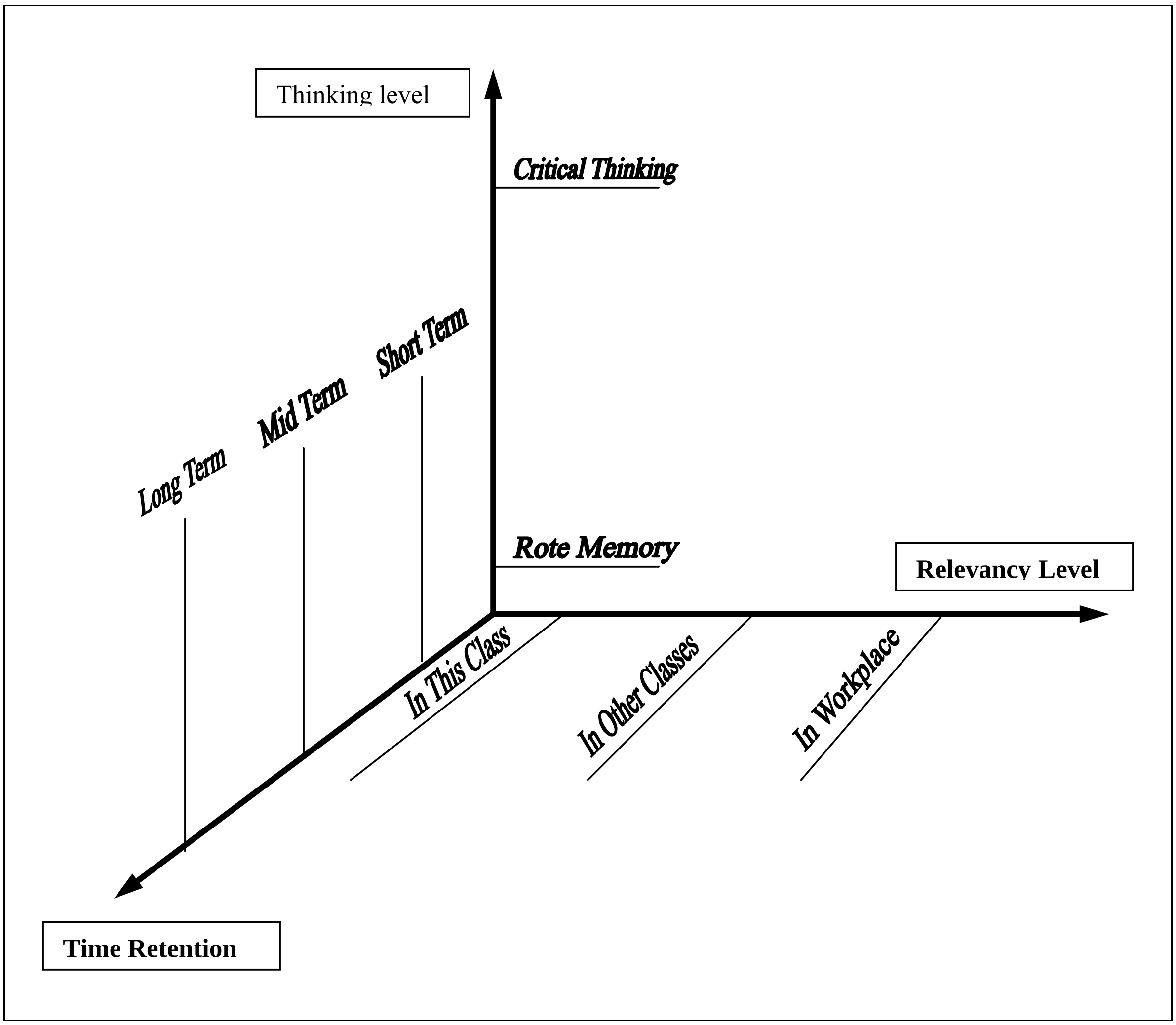

Figure 1 - Rigor/Relevance/Retention Matrix

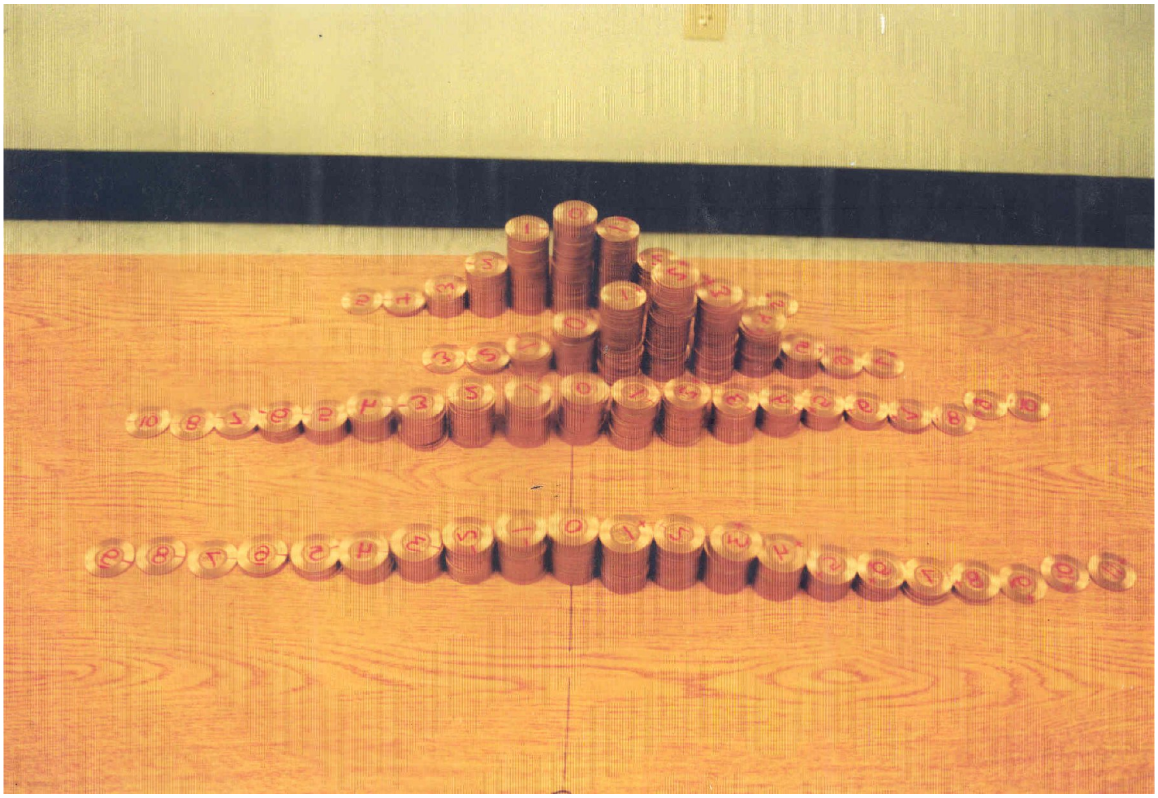

Figure 2 - Poker chips