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FOSTERING ACTIVE LEARNING IN STUDENTS OF COMMERCE AND ACCOUNTING: USING RED BEAD ACTIVITIES TO TEACH STATISTICAL CONCEPTS

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Abstract *This work describes in-class active learning activities that can be conducted using the same or similar materials to those W Edwards Deming used in his famous "red bead experiment". Specifically, the proposed activities are designed for use in the first business statistics course taught in a flipped classroom format, where having a repertoire of good in-class activities is essential for engaging students in the active learning process. In recent years, numerous active learning activities have been developed and popularised for general statistics courses, but there have been few activities developed specifically for students studying business and related fields. The activities proposed here are designed to foster active learning for students of accounting, economics, finance, marketing, management, and other fields related to business and commerce. The activities require a minimal investment in materials and can be used to supplement instruction of statistical topics including random variation, sampling distributions, estimation, and interpretation of confidence intervals.*

Keywords: *Active Learning, Business Education, Classroom Activities, Deming, Flipped, Red Bead Experiment*

INTRODUCTION

The flipped classroom is a pedagogical model in which the typical lecture and homework elements of a course are reversed. Short video lectures, or alternatively, brief reading assignments, are reviewed and studied by students out of class, while in-class time is devoted to exercises, projects, or discussions. This model contrasts from the traditional lecture model in which material is introduced via lectures in class, with students cementing understanding through out-of-class assignments; thus, the term 'flipped classroom'. A flipped classroom needs a number of components to operate smoothly and effectively. The instructor must make quality, accessible instructional material, in the form of short videos or brief reading assignments, available to students before class. The students must be conscientious in completing the out-of-class assignments in a timely manner before the corresponding class period. And finally, the instructor must have a collection of learning activities, discussions, experiments, case studies, and other exercises available to replace the traditional class lectures. Recent research indicates that students who studied statistics in a flipped classroom had greater recall compared to traditional lecture-taught students when tested 20 months later (Winquist & Carlson, 2014).

Many instructors are reluctant to move away from the traditional lecture format for selfish reasons, like not wanting to re-prep a course that they feel is currently a good course (imagine a 15-year lecture veteran who can give 50-minute lectures with little or no preparation due to years of experience and repetition). It is understandable that they may be reluctant to invest the time and energy required to properly flip a classroom. Other instructors have a desire to flip the classroom, but are intimidated by the daunting prospect of finding or developing enough activities to take the place of many lectures. It is this element that causes some instructors to cling to their traditional lecture format – they do not know how they will find enough effective class activities to effectively fill time that used to be spent lecturing.

While one of the 2005 GAISE (Guidelines for Assessment and Instruction in Statistics Education) college report's recommendations is to foster active learning in the classroom, it is difficult to engage introductory statistics students in active learning. Many writers suggest using computer simulations to illustrate statistical concepts, but that is not necessarily active learning – if the students are

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sitting and watching the instructor conduct the simulation, then it is really just another form of lecture. Many classroom activities that are developed and disseminated to the statistics education community are aimed towards science, psychology, or general studies statistics courses. Rarely is new material developed specifically for use in the business statistics classroom. Teachers of business statistics need more business-oriented active learning activities for use in the classroom. The aim of this paper is to add a few activities to the pool that teachers of business statistics can draw upon when flipping their course. These ideas are inspired by the classic red bead experiment used by Deming.

LITERATURE REVIEW

Wilson (2013) endeavoured to address some of the challenges in teaching and learning of statistics by making significant changes to an undergraduate statistics course required for social science majors. By flipping the traditional lecture/homework structure of the course, most of the basic knowledge acquisition moved out of the classroom, thereby creating room for interactive activities during class. The author documented that the flipped teaching approach brought a positive impact on students' attitudes towards the class and instructor. Further, the flipped approach improved the students' performance in the class by an average of 9.99 points in overall course grade.

Chen, Chen and Chen (2015) used Q-methodology to systematically study students' perspective of cooperative learning in a flipped statistics classroom. Q-methodology is a research method used in social sciences to study people's 'viewpoint' on a subject. Forty-five students who participated in a 16-week course were asked to rank 30 statements according to their relative importance. Three distinctly different factors that represented groups of participants with similar views were extracted. All three groups identified cooperative learning as an effective instructional strategy in the flipped classroom.

Loux, Varner and VanNatta (2016) compared a flipped classroom approach to the traditional lecture-based approach in introductory biostatistics. Their subjects were first-year graduate students in public health. The authors compared the opinions of the biostatistics field and confidence in applying the biostatistics methods of 46 students who took the flipped course, to 52 students who took the traditional, lecture-based course. The authors found similar end-of-semester opinions and levels of confidence between students in the two classes. They further document that the students in the flipped course had higher satisfaction with the course delivery model than the students in the traditional, lecture-based course.

Swart and Wuensch (2016) find that the flipped classroom is an excellent pedagogical choice for quantitative courses. They find that flipping quantitative courses leads to a reduction in "transactional distance" and increases student satisfaction with the course. They identify the "triple win" as increased student satisfaction (win for students), without sacrificing academic standards (win for instructors), leading to increased retention (win for institution). Further investigation by Swart and MacLeod (2020) find that the benefits of flipped classrooms are transferable to online courses and yield student satisfaction on par with the equivalent face-to-face course.

In a meta-analysis of 11 published studies, Farmus, Cribbie and Rotondi (2020) compared the performance of students in introductory statistics courses for non-math majors taught using flipped classroom and lecture-based classroom approaches. The authors document that the students taught using flipped classroom methods perform better than the students taught using lecture-based methods. The average difference in performance outcomes was 6.9%.

DEMING'S CLASSIC RED BEAD EXPERIMENT

Dr. W. Edwards Deming, well-known engineer, statistician, and management consultant, often used a teaching tool called the "red bead experiment" during his seminars around the world. This famous instructional experiment has been called "the single most powerful tool to illustrate concepts in statistical thinking as well as the fallacy of certain management approaches" (Boardman, 1994). Accounts of how Deming ran the experiment vary, but it typically goes something like this:

Deming usually described the activity in terms of a production operation. He used a large tub containing 20% red beads, representing defective products, and 80% white beads, representing non-defective products. Volunteers, playing the role of common workers, would dip a paddle into the container to randomly select a sample of exactly 50 beads (using a special paddle with 50 divots to ensure n = 50), representing their daily production output. Other volunteers played various supervisory and management roles, counting the number of defects in each worker's daily production and monitoring the reporting process. Deming would stand nearby and 'berate' workers for producing too many defective products each day. After several days, the managers would total the results for each worker and make decisions based on the results. They might promote or award a bonus to the worker with the lowest defect total, or fire the worker with the highest defect total.

Of course, the driver of the differences in the worker performance is random variation. Each worker is subject to exactly the same process and the difference in their performance is due only to chance. There are numerous lessons to be learned from the activity. All workers perform within a system that is beyond their control. There will always be some workers who produce above-average results and some workers who produce below-average results, due to chance. The workers' ranking within the evaluation varies from one period to the next, again due to chance. Because performance is driven by the nature of the process rather than worker effort or skill, berating workers for poor results has no effect on subsequent performance. Likewise, praise or motivational tactics do not change the process. There are many other lessons that can be discussed in association with the experiment.

Videos of Dr. Deming conducting the red bead experiment are preserved by The Deming Institute at youtube.com. The videos are typically edited and show only a portion of the exercise, but are nevertheless extremely informative. Several links are provided in the references.

A few materials are needed to conduct the classic red bead experiment. Deming used a pair of rectangular trays (Deming referred to them as "vessels"), 2,000-4,000 beads in the ratio of 80% white and 20% red, a special sample collection paddle, and a scorecard for recording and tabulating results. The paddle had 50 divots so that when it is dipped into the beads to select a sample, exactly $n = 50$ beads can be consistently selected.

Fig. 1: Sample Collection Paddle, Vessel of Mixed Beads, and Scoops

Table 1: Scoreboard

Name	Day 1	Day 2	Day 3	Day 4	Total
Ben	6	10	5	14	35
Jerry	11	11	12	9	43
John	10	13	13	6	42
Jane	10	7	5	15	37
Total	37	41	35	44	157
Average	9.25	10.25	8.75	11	9.81

Participants are recruited from the audience and assigned to one of several roles. The usual roles are willing worker, inspector, chief inspector, controller, customer, and manager/foreman. In the videos of Deming preserved on youtube.com, he appeared to favour playing the role of manager/foreman himself, while selecting from the audience six willing workers, plus two inspectors, and one chief inspector.

Deming would proceed to lay out a fictional company scenario. The company obtains raw materials of mixed red and white beads. The objective is to produce white beads from the raw material. The company has standards and each worker is expected to produce exactly 50 beads each day, hence the use of the special paddle. The workers are given "on-the-job training" as Deming demonstrates the correct procedure. The production procedure typically involved mixing the beads by pouring from one vessel to the other, then dipping the paddle into the beads to cover the paddle, agitating the paddle to remove excess beads, then removing the paddle and presenting it to the inspectors. The inspectors would each count the number of red beads, with the chief inspector verifying agreement between the counts.

Various trivial aspects of the procedure would be emphasised. For example, Deming would insist that the paddle be held at a 45-degree angle and comment when workers deviated from the proscribed angle. Workers produce samples containing various numbers of red beads, averaging about ten. Deming, playing the role of foreman/manager, would comment on the results, reminding the workers to keep the red bead count as low as possible, praising low red bead counts, and making negative comments about the higher red bead counts. After every worker has one turn, Deming declares the first day is over and the next round will represent the second day of production. On subsequent 'days', Deming would employ a different motivational technique or managerial style, each of which, inevitably, fails to improve overall performance. Deming would continue the exercise for, typically, six days, occasionally firing a worker for poor performance and mixing in other antics.

On the last day, Deming would start the day by firing half of the workers at the start and relate that they are keeping the factory open, but only retaining the best workers. Surely that will solve the problems. Criticism of poor results continues and at the end of the day, the results are tallied. Performance has remained poor and he concludes the exercise by firing the remaining workers and closing the factory.

A discussion of observations from the exercise would ensue. There are many lessons, statistical and managerial, learned from the exercise, and they sometimes vary from one instance to the next as the scenario does not always play out in exactly the same fashion.

Instructors often use variations of the experiment - see for example, Moore (2010). Instead of a red bead production company, some facilitators prefer to represent a company that processes and ships the beads, with each shipment expected to contain exactly 50 white beads. Many facilitators like to assign specific real problems that their company encounters to the red beads. The idea is to make the red beads represent a naturally reoccurring problem that cannot be completely avoided. Some facilitators will use a pre-rehearsed accomplice to demonstrate certain issues that may arise, for example, a belligerent worker who talks back to the manager or a worker who deliberately struggles to correctly follow the established procedure. Some facilitators appeal to the audience to help them make decisions on merit awards and firings.

Deming often took well over an hour to complete the exercise. As his seminars often covered one or more full days, that was not a problem. For classroom use, instructors have been known to reduce the number of workers to four, the number of production days observed to four, and use only a single inspector. These changes make it possible to complete the exercise in significantly less time – often well under an hour. A sample script for running the red bead experiment in your own classroom, along with sample scorecards and other aids, can be found at http://www.redbead.org/group_downloads/bob_daugherty_documents/red_bead_experiment_script_doe.pdf.

ALTERNATIVE BEAD ACTIVITIES

Why do the red beads represent defects? Originally, Deming used this demonstration to teach quality ideas in production settings. Dr. Deming's version is still insightful to all students of business or statistics; however, there are many students enrolled in the introductory business statistics course who have little or no interest in production or quality control. They are majoring in marketing, finance, economics, or another field where quality control will not be a large part of their undergraduate instruction or future work. There are ways to adapt this enlightening exercise to illustrate similar concepts in other areas of application that might appeal to a wider range of students.

For example, for some of the exercises, the red beads could represent positive outcomes like sales volume, successful negotiations, or any other business transaction that has a binary outcome. In these variations, students want to get high counts of red beads. The idea is to change the 'story' of the activity each time that you use the beads in class, rather than repeat the 'counting defects' scenario multiple times in a single term.

How could the bead selection mechanism change? Instead of a paddle that always selects exactly 50 beads, what about using different-sized measuring cups or scoops? With a 'sales' storyline, a large measuring cup could represent a region that is small and easily managed so that a salesperson assigned to this region can meet with many potential clients in any given time period. A smaller measuring cup could represent a more geographically challenging sales region where potential clients are tougher to reach. Is it a fair comparison to compare bead counts of these two salespeople?

How does the variation vary? That is a neat question that is often not explored in the introductory statistics curriculum. You would expect the results from the larger measuring cup to have larger means and greater variability than the results from the smaller measuring cup. Maybe students will suggest alternative methods for comparing the performance of the workers.

Here are outlines for some new activities, inspired by the red bead experiment, that are appropriate for studying topics on the introductory business statistics syllabus. They utilise the materials from the red bead experiment, with a few extra additions. The authors created their own sampling paddle in one afternoon, using scrap wood, a drill, and paint. The beads and vessels can be obtained at any store that has an arts and crafts section, or ordered online.

Thinking about Variation

Let the red beads represent successful sales for a regional salesperson. Instead of the n = 50 paddle, use measuring cups or scoops of differing sizes to sample from the vessel of beads. Larger scoops represent a sales region that is easy to navigate, while the smaller scoop represents a more challenging sales region, where the sales volume is likely to be smaller. Different-sized scoops will result in different numbers of red beads. Record the results (counts of red beads) as a stream of students repeatedly sample using the differing scoops. After a sufficient amount of data has been collected, calculate summary statistics for the resulting counts. Students will notice that the larger scoops gather larger n's, result in larger counts of red beads, and also have larger values for the variance. As the mean number of red beads increases, so does the corresponding variance. A discussion of the variability in the variation can ensue. This is a particularly useful exercise for business students because it can lead right into a discussion of the coefficient of variation and how variation must be judged relative to the mean. Comparison of investment instrument returns is a natural real-world application.

Estimating a Proportion

Use the red bead experiment concepts to study estimation of a proportion. Replace the $n = 50$ paddle with a measuring cup or scoop and focus on the proportions of the beads in the resulting samples. A good 'story' to use in this exercise is elections. The authors like to have another vessel of blue and green beads in closer proportions – around 45% and 55%, respectively. Let the sampled beads represent a sample of likely voters on the eve of an election, with the colour of each bead indicating the respondent's favoured candidate. With a more even distribution of beads, some samples are likely to favour the candidate with the smaller proportion of beads. Discuss issues such as sampling variability and elections that are too close to call. This would also be a good exercise for demonstrating that the standard deviation of the sample proportions matches that calculated from the theoretical formula.

Sampling Distributions of Proportions or Means

The red bead materials, along with the $n = 50$ paddle, can be used to study the sampling distribution of the proportion. Tabulate results in real-time as random samples of $n = 50$ beads are selected by a steady stream of students. Students observe how the sampling distribution is built up one sample result at a time. After a number of samples, the shape of the resulting sample proportions will begin to resemble the normal distribution. This could also be a good opportunity to introduce control charts. Chart the results and demonstrate that the process is 'in-control'. To illustrate an out of control process, keep a second vessel of blue or green beads in a different ratio and explain that an 'event' has happened that has changed the process – switch the vessels and let the class observe the chart signal. Similar results can be obtained by studying the sampling distribution of the mean, but requires drawing many more samples of counts and consumes more class time. To keep the exercise moving at a crisp pace, it is suggested to simply count the beads, regardless of colour, and to use very small scoops to keep the counting quick and easy.

Interpreting the Meaning of "Confidence Level"

It is very easy to use the $n = 50$ paddle and the vessel of beads to study characteristics of confidence intervals. After introducing the formula for the confidence interval for a proportion, have students select samples of 50 beads and calculate the proportion of red beads. Then calculate the corresponding 95% confidence interval. Repeat several times and create a drawing showing a growing 'stack' of confidence intervals on top of a number line. At this point in the semester, if you have used the beads before, the students likely recall that the true proportion of red beads is 20% and they can observe whether each interval covers 20% or not. The exercise would provide a solid example of the meaning of 95% confidence.

Comparing Two Proportions or Means

For studying confidence intervals and hypothesis tests for the difference of two proportions, you could use two different scoops and test that they produce equal proportions of red beads (they should). Another possibility is to prepare a second vessel containing blue or green beads. The second vessel could contain a different proportion of coloured beads than the red bead vessel. Power can be investigated by observing what happens as you take larger and larger samples from the two populations of beads.

Use the beads to study two-sample t-tests and t-intervals by taking multiple samples, counting the coloured beads, and calculating means over a number of samples. Different means can be produced by using different-sized scoops or by drawing scoops from two different sets of beads, as mentioned above.

ADDITIONAL ACTIVITIES FLIPPED BUSINESS STATISTICS

If all activities involved the beads and accessories, students would quickly tire of the exercises – undoubtedly, you will want to use other activities throughout a course as well. Here is a sampling of published activities that have worked well in business statistics courses. The "Guessing Ages" activity leads to discussions about estimation, estimate accuracy, quantifying accuracy, and variability among estimates (Gelman & Glickman 2000). The "How Large is Your Family" activity is great for illustrating sampling bias (Gelman & Glickman 2000). The "Random Rectangles" activity demonstrates the effectiveness of random sampling and its superiority over judgment sampling (Schaeffer et al., 2004). The authors like to exploit the anchoring effect by demonstrating the calculation of the area of one of the larger rectangles, thus introducing an unknown (to the students) bias into the estimates. The "Being Warren Buffett" dice game is great for business students, especially those studying finance. It demonstrates random variables, properties of a portfolio, and volatility drag (Foster & Stine, 2006). It is also quite fun. For hypothesis testing, the "Gender Discrimination Simulation" using playing cards is a great way to introduce p-values (Diez, Barr & Cetinkaya-Rundel, 2015). The simulation is conducted using randomly dealt playing cards to two stacks (representing males and females) and the p-value is generated from the distribution of the results from a number of random deals (simulations).

Of course, case studies, discussions, computer simulations, and other exercises would be mixed with hands-on learning activities throughout the semester. There are many good collections of business statistics cases and good statistics computer simulations.

CONCLUSIONS

As students change and the idea of 'flipped classrooms' grows in popularity, there will be increasing pressure to move away from lecture-based teaching and towards more active learning. Hopefully, this paper has provided some solid ideas to teach statistical concepts to business students with fun, engaging, and effective classroom activities.

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