THE BUSINESS OF TEACHING STATISTICS AS AN EXPERIMENTAL SCIENCE: OR AN EXPERIMENT IN THE SCIENCE OF TEACHING BUSINESS STATISTICS

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ABSTRACT

The results of a two semester experiment teaching business statistics as a computer lab based course, rather than a lecture based (or lecture based with lab component) course, shows that students show significant improvement in data interpretation and analysis at the cost of a slight degradation of probability technique performance. The evidence is from over 200 students (representing 3 lab sections and 1 control group section) on 5 exam questions and the course capstone project. Indirect assessments further suggest that students recognize the value of the lab approach both from the immediate rewards of deeper conceptual understanding to the longer lasting effects from future use of the techniques.

INTRODUCTION

As instructors, we should be concerned with the results of our teaching (meaning student learning) rather than any perceived glory or status involved in the method of our teaching. I mention this as I believe that the headlong rush to incorporate technology into the classroom has not been as carefully considered as it should be. One approach to any change in teaching method is to conduct a scientific experiment, using a control group and careful analysis, on the students in such a course.

This paper describes a year long experiment teaching statistics as a (computer) lab science instead of as a traditional lecture based course. Over the course of my year as a Distinguished Teaching Fellow with UW System, I developed a project analyzing the learning goals and teaching methods of the Statistics course at the University of Wisconsin - Oshkosh (Econ 210). I conducted three sections of the course with a computer lab instead of a lecture only course. The lab occupied roughly a quarter of the class contact hours.

My findings are that students in the lab based course gained a facility with computer oriented statistical analysis and lost the trepidation to approach computer work and numerically oriented problems so often found even in students who successfully completed other statistics programs. Furthermore, the students from the lab based course did not show any degradation of skill with standard statistical techniques and methods. The lab students took away with them a very important job skill. They were able to recognize their new facility with computer oriented statistical analysis with very positive comments on class evaluations as well as with continuing feedback to the course instructor over succeeding semesters.

THE EXPERIMENT AND EVALUATION METHODOLOGIES

During 2000 three sections of our normal statistics course was converted from a lecture based course to a lab based course. There were a total of 13 sections of the course offered during that time. In the Spring of 2000, only one section was converted to a lab course and students were not apprized of the change until the course begun. Sufficient other sections were available for students who wished to transfer out if they felt strongly they did not want to participate in the experiment; two students did not complete the course in the Spring of 2000. Fall 2000 saw two lab sections offered, again without notations in registration material though student word of mouth may have biased student selection of these sections; there were no drops that term.

The statistics course offered in the Economics department serves both the Economics Department majors and minors but also all majors from the College of Business. Other departments in the College of Letters and Sciences offer their own statistics courses, such as Sociology, Psychology and Mathematics. Therefore, our student base is generally rather homogenous as to major and career aspiration. All students were undergrads and the non lab section has 35% females while the lab section has 34% females. This closely follows general enrollment in the Economics Department and in the College of Business here.

The course sections under consideration here, 3 lab based sections and 1 non lab (lecture) section were all taught using the same basic text, with the same professor, at roughly the same times of day, with the same lecture notes in an attempt to keep the control group as consistent with the experimental groups as possible. All of these sections were offered three days per week, 60 minutes per day, for 14 weeks (standard course schedule at our university). Both sections has weekly homework with very similar problems on each homework assignment. The lab sections were offered in the regular chalkboard/overhead equipped lecture room twice a week with one 60 minute session moved to the university computer lab. The exceptions were on exam weeks, so there were 11 labs in a 14 week semester (two midterms and one final in the course).

Lab assignments were briefly discussed at the beginning of each lab period, with a lab worksheet handed out as well as an instruction sheet each week. The course text book also gave computer instruction and examples, though little reference was made to that source. Each assignment required data manipulation in order to obtain the required results, but further, the labs required the analysis of our empirical evidence. Students, then, were drawn into interpretation of the results as much as required to manipulate data using computer software (Minitab for Windows, Version 12). The performance on the labs themselves demonstrates facility with the computer aspect of the experiment. The professor was available during the entire lab period to answer questions and keep students on track. Perhaps because of this, students did uniformly well on these labs averaging 14 or better on each of the 15 point assignments.

Evidence about the effectiveness of that experiment was gathered in the form of the performance and opinions of those students who had taken one of these sections and compared to students who had taken regular lecture based sections of the same course from me in the succeeding semester. Specifically, I compared individual exam question results from both lab based and non lab based statistics sections to determine if the lab seems to have any direct effect on the abilities of students to handle quantitative problems. Further, I placed questions on the end of semester student opinion surveys regarding the lab experience. I also observed focus groups made up of both types (lab and non lab) of students. These groups were conducted primarily by Dr. Bryan Lily of the College of Business at our University (so that I would not bias the students' opinions), who did a parallel study of the overall effectiveness of the statistics/math component taught to undergraduate business majors.

EVALUATION AND RESULTS

Evaluation of this experiment takes two general forms. The first is the direct evidence of student learning in lab courses compared to the control group in a traditional non lab course. The primarily usefulness of using computers is to ease the computation burden on the student so there is more time for interpretation and analysis of statistical evidence. The second form of evaluation comes from the students themselves in the form of student opinion surveys regarding the perceived usefulness of using a computer based lab component in this course.

DIRECT LEARNING ASSESSMENT

For many years I have assigned the same final homework project in my business statistics courses. That project requires students to find (or create) a data set, run a regression from that data. Furthermore, students are required to analyze that regression in terms of its appropriateness and its results (see Appendix for a copy of that homework assignment for Spring 2001). All of my classes have the identical assignment, but only the three experimental sections had the benefit of a computer lab directly incorporated in to the course. The other sections had 3 (out of a total of 9) course assignments that required the use of a computer. Those other sections had no in lab direction, though I was available during office hours to answer questions regarding the computer program.

The results from the homework are summarized in Table 1, where the scores are summarized as the number of points OFF from the total available, and shown under "Points Lost." It is quite clear that the computer lab sections outperformed the lecture section in my sample. This is a key result because of the importance of regression analysis to the practitioner of statistics in the business world.

Table 1: Points Lost on Homework Project

	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	0.42	2.11	YES - lab students did better
(std)	(1.19)	(3.37)	(4.12)**
Number Graded Responses	86	38	
**Significant at 95%			

Another form of direct learning assessment comes from exam scores on particular questions. Beginning with the second exam, where statistics (as opposed to probability) is directly tested, certain questions were placed on exams for both the lab sections and non-lab sections of the statistics course. The following two questions were on the second midterm in the Fall of 2000 and in the Spring of 2001.

I was very careful to keep and use a very thorough answer key in order to keep the partial credit grading as consistent as possible, the scores are the number of points OFF from the total available, and shown under "Points Lost." The conclusions, drawn by the students in each problem, are shown under "Conclusion." Significance tests were performed at the 95% (5% significance) level.

The first question uses a one sample t test technique. Students were free to perform use the p-value for testing the proposition or a cutoff t-test or a confidence interval test. They were required to report the p-value, however.

> A national publication reported that a college student living away from home spends, on average, no more than $15 per month on laundry. You believe this figure is too low and want to disprove this claim. To conduct the test, you randomly select 30 college students and ask them to keep track of the amount of money they spend during a given month for laundry. The sample produces an average expenditure on laundry of $17.12, with a standard deviation of $4.52. At 95% confidence, do students really spend only $15 per month? Show all work and state your conclusion with a FULL sentence. Also, report a p-value. 17 pts.

The results from this exam question are as follows:

Table 2: Points Lost on Exam Question

	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	1.89	1.48	NO
(std)	(2.45)	(2.15)	(.89)
Conclusion (correct=1)			
Average	.93	.90	NO
(std)	(.258)	(.304)	(.51)
Number of Graded Responses	57	40	

This question has two important parts: 1. The mechanics of the statistics (evaluated by the overall score for the problem) and 2. The correctness of the conclusion *based on the mechanics as performed* (evaluated by 1=correct and 0=incorrect). Note that an evaluation of "1" could be given to the incorrect answer of "No, these groups do not have statistically different proportions at the 95% confidence level" ***IF*** the incorrect numerical work in the problem supports that answer of 'no difference.'

There is no statistical difference between either the technical manipulation involved in the problem or in the conclusion reliability on this problem. Though, there is a very slight raw score difference showing better technical skills in the non lab section and better conclusion reliability in the lab section.

The second identical question used a two sample proportion technique. Again students were free to choose method, but had to report a p-value and state a clear conclusion. That problem follows:

A study of female entrepreneurs was conducted to determine their definition of success. The women were offered optional choices such as happiness/self fulfillment, sales/profit, and achievement/challenge. The women were divided into groups according to the gross sales of their businesses. It seems that a higher proportion of female entrepreneurs in the $100,000 to $500,000 category than in the less than $100,000 category seemed to rate sales/profit as a definition of success. Does the raw data (given below) support this conclusion at a 95% confidence level? Show all work and state your conclusion with a FULL sentence. Also, report a p-value. 17 pts.

	Less than $100,000	Between $100.000 and $500,000
n	100	95
sp	.24	.41

The results from this exam question were as follows:

Table 3: Points Lost on Exam Questions			
	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	2.82	2.08	NO
(std)	(3.83)	(2.52)	(1.16)
Conclusion (correct=1)			
Average	.649	.75	NO
(std)	(.481)	(.439)	(1.07)
Number of Graded Responses	57	40	

Results are reported as for the previous questions. Again there is not statistical difference between either the total score (points lost) or the accuracy of the conclusion at the 5% significance level.

Three identical questions were placed on the final exams for all students. The first is a problem that combines a t test with a probability calculation:

Data accumulated by the National Climatic Data Center shows that the average wind speed in miles per hour for Chicago, Ill. is 10.3. Suppose wind speed measurements are normally distributed for a given geographic location. Let the standard deviation of wind speed in Chicago be 4 mph.

1. What is the probability that the wind speed on a randomly selected day is 11.3 or greater? 5 pts.
2. Chicago has the nickname of the "windy city", lets see if that is true. Suppose that on 25 randomly selected days we measure the wind speed in St. Louis Mo. and find an average wind speed of 9.7 with a standard deviation of 3.6. Can we really say, at 99% confidence, that Chicago is the "windy city" (at least compared to St. Louis)? 5 pts.

The results from this exam question are as follows:

Table 4: Points Lost on Exam Question

	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	4.60	3.33	NO
(std)	(3.27)	(3.10)	(1.94)
Conclusion (correct=1)			
Average	.439	.525	NO
(std)	(.501)	(.506)	(.83)
Number of Graded Responses	57	40	

The lab students lost more points on the mechanics of the question (though still not significant at 5%, two tailed test) as well as had slightly lower accuracy on the conclusion. As the computer portion of the course was used primarily for data manipulation (statistics) and less for probability calculation (even for distributions), it is, perhaps, not so surprising that a problem that includes manipulation of a probability distribution poses more difficulty for the lab students.

The second statistical problem on both finals required a two sample proportion technique (again):

> A company's market share is very sensitive to both its level of advertising and the levels of its competitors' advertising. A firm known to have a 56% market share in the past wants to test whether or not this value is still valid in view of recent advertising campaigns of its competitors and its own increased level of advertising. A random sample of 500 consumers reveals that 298 of them use the company's product. Is there evidence to conclude that the company's market share is no longer 56%? Has it increased or decreased? Make your conclusions explicit. 9 points (total)
> a. Test at 95%
> b. What is your ultimate conclusion? Explain.

The results from this exam question are as follows:

Table 5: Points Lost on Exam Question			
	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	3.44	3.05	NO
(std)	(3.39)	(2.89)	(.61)
Conclusion (correct=1)			
Average	.509	.475	NO
(std)	(.504)	(.506)	(.32)
Number of Graded Responses	57	40	

Once more, the lab students did slightly worse at computation but slightly better at the accuracy of conclusion. Still, however, these results were not statistically significant.

The last identical problem on both sets of exams was a pure probability problem. I wanted to see if the lab students were truly missing out on probability. This question was just a basic counting problem using combinations.

A publishing company publishes five different how-to books, and it has a special offer of three books for $10. A woman has decided to buy three books and give them to her husband one at a time to entice him into making three desired how repairs. In how many ways can three books be selected and ordered from the list of five books? 5 pts.

The results from this exam question are as follow:

Table 6: Points Lost on Exam Question

	Lab Course Sections	Non-Lab Sections	Significant Difference? (T-Statistic)
Points Lost Average	2.32	1.5	YES-lab students did worse
(std)	(1.99)	(1.96)	(2.00)**
Number of Graded Responses	57	40	
** Significant at 95%			

As no analysis was required by this problem, the only data acquired was on the accuracy of the computation. The students from the lab course did do significantly worse at the 5% level at probability computation.

The preceding results show, at the 5% significance level, no difference between the statistical problem solving skills acquired by students that took the course with a lab setting or without the lab component. There is a small, but significant, difference between the probability skills acquired by these students. The non-lab students performed better on that type of skill. This is no surprise given that the computer is really of very little value for solving these types of problems. I do not consider this an insurmountable difficulty for the lab based environment, however, as I would venture to guess that very few employers place higher importance on probability skills rather than statistical ones.

STUDENT OPINIONS ABOUT THEIR LEARNING EXPERIENCES IN STATISTICS

Student evaluation surveys from the three lab based statistics sections had extra assessment questions added to the regular course evaluation instrument regarding the value of the lab experience. Students were also encouraged to express sentiments in a more free form fashion in the 'open comment' section of the instrument. As these responses are only given to the professor after course grades are assigned and all written comments are typed to preserve student anonymity.

This first set of comments and results are from the second semester of the experiment, after some modifications to the labs were made. In Fall 2000, those questions (numbered 35-39, on the survey instrument) were:

35.	Did the lab component of this course aid in your understanding of the course material?
36.	Did the lab component of this course encourage you to try using course material for other courses in the future?
37.	Lab is a valuable addition to courses of this type.
38.	I learned something in the lab component of this course.
39.	The lab component of this course should be eliminated.

The table below summarizes the responses from Fall 2000 (number of responses, with percentage responding in parenthesis):

Table 7: Student Survey Responses
(percentage responding in parentheses)

Questions	mn 2	mn 3	mn 4	mn 5	mn 6	mn 7	mn 8
	1 Strongly Disagree	2 disagree	3 in between	4 agree	5 strongly agree	# responding	Mean
lab aided understanding	0	8	3	15	20	46	4.02
	(0)	(17.4)	(6.5)	(32.6)	(43.5)		
lab encouraged future use	1	2	17	20	6	46	3.61
	(2.2)	(4.3)	(36)	(43.5)	(13)		
lab is valuable	2	2	4	17	20	46	4.04
	(4.3)	(4.3)	(8.7)	(37)	(43.5)		
learned some thing in lab	2	2	4	21	16	46	3.95
	(4.3)	(4.3)	(8.7)	(45.6)	(35)		
lab should be eliminated	27	11	2	2	2	44	1.65
	(61.4)	(25)	(4.5)	(4.5)	(4.5)		

Generally, it appears from this data that fewer than 10% of the students think lab should be eliminated. An overwhelming majority think that lab is valuable and encouraged future use of computers.

The comments from student evaluations relevant to the lab set up were:
I liked the lab, helped make the course more realistic and useable
I think the lab helped put the lectures into perspective.
The lab was very helpful and challenged me. It added a different technique for learning the material. It showed us how to put the material we learned to work.
I enjoyed the lab. It was a lot better than (other prof's) computer assignments.
This is the second time I took the course and I feel it was much more beneficial with the lab, it was a nice change of pace on Friday and it allowed me to lean the material quicker & better.
Lab helps not only with this class but helps to familiarize with the computer and programs in general.

These comments are particularly gratifying because there were no negative comments concerning the lab component of the course in the Fall 2000 evaluations. It even appears that students were actually getting what we want them to get: reinforcement of techniques and familiarity with common statistical software.

The first semester of the experiment was not quite so positive, but still overwhelmingly positive. The survey instrument for Spring 2000 had the following additional questions (numbered 35-39):

35.	I have learned something in the lab portion of this course.
36.	Lab is a valuable addition to courses of this type.
37.	The labs in this course need a major overhaul.
38.	The labs in this course need a minor tune-up.
39.	The labs in this course need to be eliminated.

The following table summarizes the responses for Spring 2000:

Table 8: Student Survey Responses
(percentage responding in parentheses)

Questions	mn 2	mn 3	mn 4	mn 5	mn 6	mn 7	mn 8
	1	2	3	4	5	#	Mean
	strongly disagree	disagree	in between	agree	strongly agree	responding	
Learned something in lab	1	0	4	16	6	27	3.96
	(3.7)	(0)	(14.8)	(59.3)	(22.2)		
labs were valuable	2	0	5	12	8	27	3.89
	(7.4)	(0)	(18.5)	(44.4)	(29.6)		
labs need major overhaul	2	16	6	1	6	27	2.44
	(7.4)	(59.3)	(22.2)	(3.7)	(7.4)		
labs need minor tune-up	0	1	9	14	3	27	2.44
	(0)	(3.7)	(33.3)	(51.9)	(11.1)		
lab should be eliminated	13	10	1	0	0	24	1.5
	(54.2)	(41.7)	(4.2)	(0)	(0)		

While there were no students that expressed the opinion that labs should be eliminated, there were three students that indicated that labs needed substantial revision. Still, the general results from the student opinion surveys indicate that students liked the lab component of the course.

Student comments from the "free comment" section relevant to the lab experience from Spring 2000 were:

I do like the labs for the reason that they are easy points to bring your grade up.
About the labs: I think initial stuff should be take home assignments. We use minitab without know (sic) what we're doing a lot in lab.
Having taken this stats course before (different instructor) I feel that the labs are a highly effective way of learning in a practical manor. (The early labs need a bit more work - maybe hand out directions for the lab the period before lab)
Make the labs relate to what is learned in class. Talk for the first 5 minutes of the lab to explain the connection.

These suggestions, in particular taking more attention to explain how to use the software program were implemented in the succeeding semester.

The general gist of these opinions shows student opinion to be strongly in favor of the lab (see particularly the results from the 'lab is valuable' and 'I learned something in lab' questions). It is fairly clear that students really appreciated the lab, though some apparently liked it primarily for "easy points!!"

A second method of gathering opinions about a lab based component to the statistics course was obtained by the use of focus groups. Congruent with this study of the lab based statistics course is an ongoing project to evaluate the overall mathematics/statistics component of the Business major core. Two groups with a total of 17 students were drawn randomly from a business marketing class (for which math/stats is a requirement) on 11/16/00. Two professors (Drs. Burnett and Lily) presided over the sessions. A list of questions were agreed upon beforehand and were asked of both sessions. Those questions and the responses from the group are reported below. Each section has students that had a substantial experience with computers in the statistics course, although some of the students who identified themselves this way took a traditional lecture based course that required frequent computer homeworks (done outside of the class setting) with Professor K. McGee.

Computer readiness:	Do you feel prepared to use computer statistics programs on your own projects? If so, how did you get introduced to this type of computer usage?
Lab Students:	Yes. Most of these students had little exposure to any type of statistical or empirical program before statistics.
Non-Lab Students:	Generally, no. Most of these students had no exposure to any empirical programs at all before statistics and only those with Professor McGee felt they had enough homework using computers that they felt they could use them on their own..
In -class computer usage:	Do you feel that you need more in-class work with computers? In essence, what are your feelings toward computer labs in the math/stats sections?
Lab Students:	Generally the students really liked lab.
Non-Lab Students:	Most non lab students thought a lab would be a good idea, though students who had taken professor McGee were exposed to computer programs as homework assignments.

Knowledge versus memorizing:	To what degree do you understand the concepts as opposed to memorizing mechanically how to solve very specific problems? In other words, do you feel that you would be able to use the course concepts and apply them to new problems that you have not seen before?
Lab Students:	One comment that they just learned 'what' to do, instead of why.
Non-Lab Students:	Very few thought they had any handle on the 'whys' though most of both groups of students could recognize an empirical problem that required statistics.
Retention:	What do you retain from these classes and what do you not retain?
Lab Students:	Mostly the statistics, not the probability.
Non-Lab Students:	Most claimed to retain very little.
What material from these classes do you see being used in later classes? What material and what classes?	
Both types of students agreed they saw this material in Marketing to some extent and in Econometrics (for those that had taken it). Many of these students were fairly new to the major and so had not taken a lot of upper division courses, however.	
Do the math and stats courses seem connected or disconnected from each other?	
Lab Students:	Disconnected.
Non-Lab Students:	Disconnected.
Critical thinking:	Does your experience in stats/math aid your ability to think critically?
Lab Students:	Yes.
Non-Lab Students:	Some thought so, others thought it was just another 'time waster' of a class.
Using data:	Do you feel you have been taught how data can be used and how it is often abused?
Lab Students:	Yes.
Non-Lab Students:	Those that had taken either Burnett (in a non lab setting) or McGee thought they did.

The focus groups had much discussion that seemed to support the idea of a lab in the statistics course and for a general reformulation of the requirement in general. There were several specific comments that suggested a more cogent course grouping and tighter content control would be welcomed. Several students thought the disparity between topics taught and emphasized among different sections of the course was too large.

CONCLUSIONS

In general, my results show that students do significantly better on computerized regression analysis that requires the use of data interpretation. They demonstrate no substantial skill degradation with statistical (as opposed to probability) techniques with the lab set up. Further, they seem to appreciate the lab experience, and are more likely to believe they will use the material in the future. That leads to my recommendation that statistics sections move to a lab format. Moreover, I would suggest that emphasis be placed on analysis and interpretation of results rather than on computation as the computer makes number crunching by hand increasingly obsolete for practitioners.

APPENDIX

Homework # 9	
This homework cannot be dropped	
This is the homework you've been waiting for. As discussed previously in class, you get to be a bit creative (with the subject matter, not the methodology!!).	
The assignment is to design a regression, run it, test it and give me your conclusions.	
You may collect the data yourself, either through a survey you take personally or through the library (gov. documents section is a good place to go for economics data), or you may use the Statistical Abstract of the United States that is on reserve in the economics dept. office.	
I expect you to turn in :	
1.	An explanation of why you chose the regression (why do you think that your x's predict what y?).
2.	Explain how you collected your data and where it came from. Was it a survey (include a copy of the questions you asked)? How was the survey conducted (who was asked)? Was the data from a government document(which one)? Was the data from the internet (what URL, what source)?
3.	What did you expect (before you ran the regression) in terms of signs of the slopes (for slopes>0, for instance - should higher levels of the independent variable be associated with higher or lower levels of the dependent variable).

Homework # 9	
4.	A computer printout of the data (I want df$25 and I would prefer df$40), I would much prefer a multiple regression (more than 1 type of x).
5.	Output from your regression.
6.	Tests of the slopes. Which were significant? Did it match what you expected?
7.	Conclusions - was the regression any "good", if so why, if not why not (look at both the goodness of fit and the signs/ significance of the slopes). Did you prove what you wanted to prove? If there were problems with the regression, what steps should be taken to overcome them?
This should be a couple of pages of computer output, and maybe a page of writing (maybe two if you write really big, I'm not looking for a tome here). Either write neatly, print, or type (if your writing is illegible).	
This should actually be sort of fun. I'm looking for some facility with the skills we have been learning, nothing more. Your grade will be based on how you display your grasp of the class material, not whether your regression "worked".	

ENDNOTES

1 The text was Basic Statistics for Business and Economics (3rd edition), Doublas A. Lind, Robert Mason and William Marchal, Irwin/McGraw Hill, 2000. The author taught each of the sections mid-day with existing lecture notes adjusted for time constraints as noted.

2 A full set of lab materials are available from the author.

REFERENCES

Lind, D.A., R. Mason & W. Marchal. (2000). *Basic Statistics for Business and Economics* (3rd Ed.), New York: Irwin/McGraw Hill.

ECONOMICS ARTICLES