ENHANCING STATISTICAL LITERACY AND THINKING THROUGH ANALYSIS OF SCIENTIFIC JOURNAL ARTICLES

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One of our major goals in teaching "applied statistics" is to train the "novice" to think and act like a statistical "expert". We have shown that: 1) Teaching from scientific articles plays an invaluable role in demonstrating how "experts" use statistical methods to solve "real world" problems, and communicate scientific findings. 2) Having students analyze scientific articles in groups, along with virtual or actual office hours with the instructor, and writing the results of their critiques trains them to "think" and "act" like a statistical expert. We have developed an online "article bank" with articles from multiple disciplines. For each article, we have designed multiple-choice and open-ended questions and answers for testing knowledge of statistical methods plus issues related to design, sampling, results, and conclusions.

BACKGROUND

During the last decade and especially after development of the Guidelines for Assessment and Instruction for Statistics Education (GAISE) by American Statistical Association (Garfield et al, 2006), the teaching of statistics has been revolutionized. Large and real data with context have replaced the small and fictitious data sets. The course content has shifted from a heavy lean on probability and theory to exploratory data analysis and emphasis on conceptual understanding of statistical concepts rather than following stepwise procedures and recipes. Additionally, the use of technology and computer software has made it possible to make the majority of calculations and graphics automated (Cobb, 1993; Moore, 1998; Singer & Willet, 1990).

Prior research conducted by Esfandiari resulted in two cyber-based tools, "an automated multiple-choice test bank" consisting of 2000 questions and "an automated essay grading system" that were successfully implemented in formative evaluation of student learning and enhancement of teaching in large lower division and upper division statistics classes (Bloom et al, 1971; Esfandiari, et al. 2011; 2010; 2009; 2008; 2006). However, none of the above cyber-based tools allowed the students to see the "big picture" and experience how statistics is implemented in the different phases of scientific research. The step we took toward solving this dilemma is the development of the infrastructure that we called a "cyber based article bank".

This article bank includes refereed journal articles from fields that demonstrate the application of statistical methods in a variety of contexts. These articles are catalogued by statistical methods including exploratory data analysis, simple inferential techniques such as one and two sample tests, simple regression and correlation techniques, and more advanced statistical methods such as ANOVA, ANCOVA, MANOVA, MANCOVA, multiple linear regression, logistic regression, time series, and hierarchical modules.

PROPOSED MODULE UNDERLYING IMPLEMENTATION OF THE "CYBER-BASED" ARTICLE BANK

The proposed module is based on theories of knowledge acquisition (Clark et al, 2008; Wittorck, 1992) evaluation of student learning, cooperative learning (Slavin, 1990; Webb, 1989), and teaching.

The major goal underlying this module is: 1) to show the novice how statistics is implemented in the different phases of scientific research and, 2) demonstrate the steps that can be taken to enable the "novice" learners in our lower and upper division statistics classes see the "big picture" and get a feel of how a "statistics expert" thinks and approaches problem solving.

IMPLEMENTATION

Based on the below schematic (Figure 1) our students develop declarative and strategic knowledge of statistics through quizzes, labs, lectures, and homework. Declarative, descriptive, or propositional knowledge includes factual information stored in memory, is static in nature,

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describes things events, and processes, shows the relationship between things, events, and processes, and is knowledge about problem solving. Procedural knowledge or imperative knowledge is knowing how to perform, operate, directly apply the knowledge to solve real world problems, and have a better understanding of the limitations of the specific solutions. Based on the above model, we are proposing that reading, analyzing, and writing critiques of scientific and refereed journal articles that cover the statistical methods discussed in the course, enables the students to synthesize their declarative and procedural knowledge of statistics, learn how to think like an expert, and see the big picture.

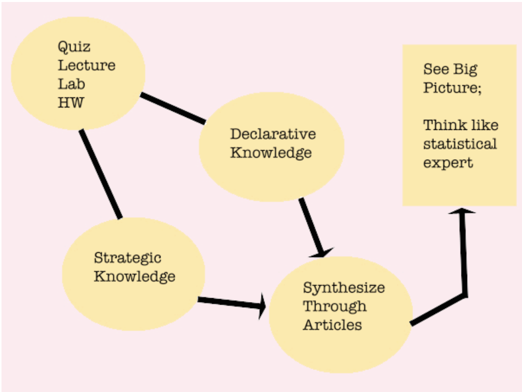

Figure 1: Schematic of the proposed module

Once the students learn how to think like an expert, they: 1) will not try to fit the problem at hand to the models learned, rather they try to fit the model to the problem that needs to be solved, 2) will not get lost in details and see the big picture, 3) will not feel insecure if the familiar recipes, stepwise solutions, and calculations are taken away, 4) will be aware of practical significance and plan for it, and 5) will be able to communicate the results of complex statistical analysis in such a way that consumers of statistics can understand.

IMPLEMENTATION

In the first week of the quarter the students were placed in groups of five (with each group member selected from the top 20% to the bottom 20%). This was done based on the University of California at Los Angeles (UCLA) GPA or performance in review quizzes. At the end of the quarter the students took a survey that measured perceptions of their ability to generate their own knowledge, think like an “expert”, communicate statistical findings, and engage in statistical thinking.

After introduction and/or revision of hypothesis testing, two to four articles were assigned, and the students were required to: 1) read the assigned articles individually and answer a number of open-ended questions, 2) meet with their group and discuss the answers to the questions, meet with the instructor/TA in actual or virtual office hours to discuss the article further and clarify potential ambiguities, and 4) write a group report answering the open-ended questions.

The “Cyber-based article bank” was implemented in teaching large and small lower division and upper division classes in “Statistics for Biological Sciences”, “Statistical for Social Sciences”, “Introduction to Experimental Design”, and “Introduction to Linear Models”.

RESULTS

- Actual and virtual office hours were equally effective in improving the students’ declarative and strategic knowledge of statistics as measured by scores on the final exam, articles, homework, and quizzes. This was true for both ten-week quarter and six-week summer session.
- Students exposed to actual and virtual office hours did not differ with respect to the perception of their ability to generate their own knowledge, think like an “expert”, communicate statistical

findings, and engage in statistical thinking. This was true for both ten-week quarter and six-week summer session.

- The students with above and below average UCLA GPA, found the lecture, articles, and the project to be the most effective part of the course with respect to helping them learn the major concepts and strategies taught in the course.
- No difference was found between the results obtained in the regular quarter and ten-week summer session.

Sample plots and tables resulting from implementation of the prototype of the Cyber-based articlebank (Figure 2, Table 1):

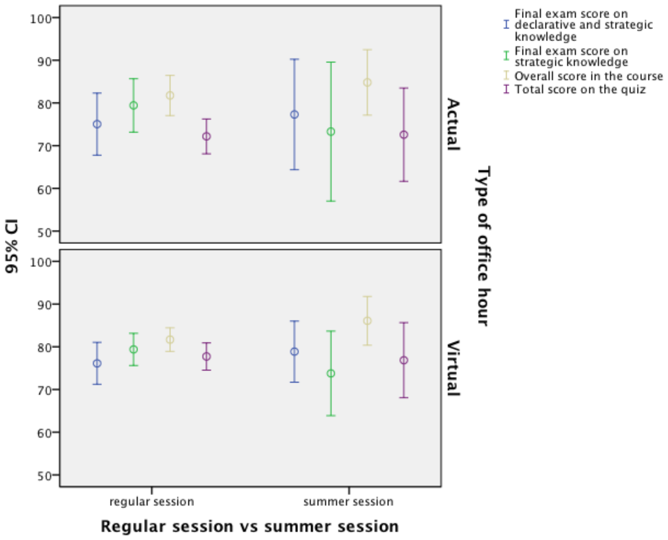

Figure 2: Plot of declarative and strategic knowledge as measured by score on the final exam, overall score in the course and quiz by type of office hours and session.

Table 1. Sample table: N, mean, standard deviation, and P values by type of office hour and session. Based on the P values reported, actual and virtual office hours were equally effective in enhancing declarative and strategic knowledge and this was true for the regular quarter and summer session

Students' scores on. …	Actual office Hours			Virtual Office Hours		
	Regular session N= 44 Mean (SD)	Summer Session N = 10 Mean (SD)	P	Regular Session N = 44 Mean (SD)	Summer Session N = 10 Mean (SD)	P value
Total exam score on declarative and strategic knowledge	74.1(23.9)	77.3(18.1)	0.781	76.2(18.4)	78.9(12.9)	0.589
Total exam score on strategic knowledge	79.4(20.6)	73.3(22.7)	0.407	79.4(14.1)	73.7(17.9)	0.200
Overall score in the course	81.8(15.5)	84.8(10.7)	0.577	81.7(10.4)	86.1(10.3)	0.148
Total score on the quiz	72.2(13.4)	72.6(13.3)	0.953	77.7(11.9)	76.9(15.8)	0.816

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