STATISTICAL THINKING AND CASE STUDIES

Harshini Fernando
Purdue University North Central
Mathematics, Statistics and Physics Department
1401 S. US 421
Westville, IN 46391
hfernando@pnc.edu

Abstract
This paper presents how case studies in statistics can be used to enhance statistical thinking among undergraduate students. The paper describes in detail what "statistical thinking" is, and definitions and statements related to statistical thinking. Also the paper presents how and why case studies should be incorporated in the undergraduate curricular. Finally the paper proposes effectiveness of incorporating a case study course in the statistics minor/major as a capstone course. Also give some insights about the statistics minor implemented at my institution Purdue University North Central, where we introduced a case study course as a capstone course.

Introduction
The importance of statistical thinking has been recognized long before now. The famous writer H.G. Wells (1866-1946) commented: "Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write". That day has come! The statement is a very true and interesting, and it makes even more sense today. In today's world decision making and learning are increasingly dependent on evidence from data. To deal and understand today's world people should understand how statistics can be used correctly. Most universities and colleges want their graduates to understand and know how to apply statistics. One effective way to do this is through introducing case studies in the curricular. The goal of this paper is to give in depth understanding of statistical thinking and to provide suggestions to incorporate case studies in the undergraduate curricular, inorder to improve statistical thinking among students.

Statistical Thinking
This section considers the following questions: *What is statistical thinking? Is it altogether a different kind of thinking?* More recently the term *statistical thinking* has taken on a broader meaning. In the early 1990s, there has been an increasingly strong call for prominent statisticians to develop students' statistical thinking. According to Snee (1999), statistical research, practice, and education are entering a new era, one that focuses on the development and use of statistical thinking. Numerous research papers and books have being written, which address what is statistical thinking.

To answer the question, "*What is statistical thinking?*", next we will consider the fundamental concepts and several definitions in detail, which are of great importance and interest. Moore (1990) summarized the core elements of statistical thinking as follows:

the omnipresence of *variation* in process; the need for *data* about processes; the design of *data production* with variation in mind; the *quantification* of variation; the *explanation* of variation. To further promote on this manner of thinking, the American Statistical Association (ASA) adopted the following list of elements of statistical thinking, as recommended by the ASA's joint curriculum committee with the Mathematical Association of America (Cobb 1992): the need for data; the importance of data production; the omnipresence of variability; the measuring and modeling of variability. The meaning of statistical thinking was also discussed by Wild & Pfannkuch (1999) in their paper, and stated the five types of thinking that were identified as fundamental elements in statistical thinking as: recognition of the need for data; transnumeration; consideration of variation; reasoning with statistical models; integrating the statistical with the contextual.

Several more definitions on statistical thinking are given in the quality management area. Snee (1990) defined statistical thinking in quality improvement sense as the thought processes, which recognize that variation is all around us and present in everything we do, all work is a series of interconnected processes, and identifying, characterizing, quantifying, controlling, and reducing variation provide opportunities for improvement. According Glossary and Tables for Statistical Quality Control, published by the American Society for Quality (ASQ) (1996), statistical thinking is the philosophy of learning and action based on the following fundamental principles: all work occurs in a system of interconnected processes; variation exists in all processes; understanding and reducing variation are keys to success. Also the ASQ the statistics divisions' effort in the regard of promoting on statistical thinking resulted in the book titled *Improving Performance Through Statistical Thinking* (2000).

All definitions and statements on statistical thinking address how to make sense of data. In summary statistical thinking involves collection and analysis of data to estimate and reduce variation. "Statistical thinking" is the process that is used when approaching or solving real-world problems, and it is too important to left to statisticians. To deal with the complexity of today's world, people should understand how statistics can be used to analyze and present information. The use of statistical analysis is growing at a remarkable rate. Most universities and colleges want their graduates to understand and know how to apply statistics correctly.

Old Proverb: *To guess is cheap. To guess wrongly is expensive.*

Many introductory statistics courses contain too much material. There is a growing recognition that we need to change the way undergraduate statistics is taught. Usually in a traditional undergraduate statistics class, with the load of material being covered, it is difficult to motivate students and develop statistical thinking. Cobb (1991) in his treatise, Teaching Statistics: More Data, Less Lecturing, commented: "*lectures don't work nearly as well as many of us would like to think*". If students don't understand concepts, there's little value in knowing procedures. We need to walk away from the traditional overview of statistics as a discipline that relies just upon formulae and procedures. Major emphasis

should be on students understanding of statistics, use and its value. Also it is essential to present statistics as an interdisciplinary approach that allows the students to use statistics to answer real world situations and communicate statistically. One affective way to introduce statistical thinking to students is through incorporating "Case Studies" in the undergraduate curricular.

How and Why Case studies

Herreid (National Center for Case Study Teaching in Science - NCCSTS) states, "case studies are stories with an educational message". A case study is a story, vehicle for discussion, analysis, and learning. The value of case study learning for students in a statistics class is that it makes them look beyond the formulas and focus on the underlying ideas, concepts and sharpen their statistical thinking skills.

Case studies can be done parallel to the course, as a final project of the course or teach statistics concepts through case studies. There are many challenges that when incorporating case studies into a course. Generally it is argued by instructors that conducting case studies in an undergraduate statistics course is time consuming and the students do not have the necessary degree of theoretical framework to carryout the case study analysis.

My proposal is implementing a case study course as a capstone course in an undergraduate statistics minor or major. Then the students are better equipped with the statistical methods and concepts to perform the case study analysis. Case studies can be used to motivate students to explore the concepts of statistics. Also the time spent on the cases will be well worth the effort. Another way to conduct case studies is teaching the statistics course as a laboratory class, where case studies are done in the laboratory work for the course. Dick Scheaffer, noted "statistics should be taught as a laboratory science, along the lines of physics and chemistry".

Case study can be done as the whole class, small groups or individually. Instructor guidance is always advisable. Depending on the case, instructor could give an overview of the study; the questions to be answered; ideas for relevant data analysis and tests of assumptions and review of any specific statistical methods and theory needed. Students could work on the case, analyzing the set of data and discussing questions about these data sets. Finally students need to interpret the results and present a report about the case. Case study report can be in written form and/or oral presentation. In a typical report, sections included: summary, problem statement/data, methods, analysis and conclusion. Case studies often has more than one answer, and depends on assumptions and problem definition. Instructor will be more interested in the analyses and process than in absolute correctness. Through case study method, students written and oral communication skills can be improved.

With the tremendous availability of quality statistical software (SAS, MINITAB, SPSS, R, Excel, etc.) it is always good to expose the students to much software as possible. Some class time and different cases could be used to introduce the software. Cases

involving could be experimental research (surveys, questionnaires, fieldwork), tailored cases looking mainly at conceptual statistical ideas, or students can design simple experiments and collect their own data.

First when attacking the case, it will be too much but later it will be not enough. Small data sets can be used to practice data entry and to do the analysis manually if necessary. Larger data sets could be made available electronically, to perform computer based case study analysis. Some questions to consider when teaching with case studies: Where would you place case study in your course? What content would you cover? How would you assess student understanding? How to get cases? In-class or outside-of-class work? Use of technology?

It is very essential to use up-to-date cases, to make the class interesting. Real world cases could be found from newspapers, news programs, science journals, databases, articles and web sources. Another option is to use casebooks as the primary source of case assignments needed for the class. Now most of the traditional statistics textbooks published, case studies are available for each chapter. Service learning is another growing area which could be used for case study based classes. In addition another source to gather data could be from class activities and simulation studies.

Case study method is an effective tool for increasing student engagement in statistics. The practice of bringing real-word application problems into statistics education is growing in general. Improved statistical computer packages and the easy access to internet based data sets have expanded significantly. Using case studies in a statistics class, introducing real world situations, it makes the class interesting. Also decision making may become easier and better quality, and students learn working in teams. Finally, through case studies students understand what they are doing, the need for data; collecting data well; omnipresence of uncertainty; variability's impact on decision making and the whole picture, "statistical thinking". Old Proverb: *Tell me, I'll forget. Show me, I may remember. But involve me and I'll understand.* Incorporating case studies, prepare students to be life-long learners.

Introducing a Case Study Course

Recognizing the need of statistics for the undergraduate students, at my institution Purdue University North Central (PNC), an undergraduate statistics minor was introduced in 2009. The undergraduate statistics minor has a minimum of 15 credit hours, where the students have to select the following:

One of STAT 225: Introduction to Probability or
STAT 311: Introductory Probability.

One of STAT 301: Elementary Statistics or
STAT 350: Introduction to Statistics or
STAT 503: Statistical methods for Biology or
PSY 201: Introduction to Statistics in Psychology or
PSY 203: Introduction to Research Methods in Psychology.

Both of STAT 361: Applied Regression Analyses and
STAT 362: Experimental Designs
One of STAT 363: Sampling Techniques or
MET 451: Manufacturing Quality Control or
STAT 465: Case Studies in Statistical Methods.

At our institution the implementation of the statistics minor is at the very introductory level. We hope the statistics minor will be a good option for any student in any discipline to have a good background in statistics, and will be a popular choice.

In the PNC statistics minor, the case study course introduced is for the undergraduates who have completed the pre-requisites: calculus, statistics, probability, regression analysis and experimental design. As the case study being the capstone course, we hope that our students will be well prepared for the course with the necessary knowledge. Hence the students will have a better understanding about how to deal with data, uncertainty and its effect on decision making, ability to think statistically, finally "the big picture", which will be useful and important above and beyond towards their future careers.

References

1. Britz G.C., *"Improving Performance Through Statistical Thinking"*, ASQ Statistics Division, ASQ Quality Press, Milwaukee, WI (2000).
2. Cobb, G. (1991), "Teaching Statistics: More Data, Less Lecturing" in *Teaching* Statistics-*Resources* for Undergraduates, T. L. Moore (Ed), published jointly by Mathematical Association of America and American Statistical Association, pp. 1-5.
3. Cobb, G. (1992), "Teaching Statistics," in *Heeding the Call for Change: Suggestions for Curricular Action*, L. A. Steen(Ed), MAA Notes No. 22, Washington, D.C.: Mathematical Association of America, pp. 3-23.
4. Glossary and Tables for Statistical Quality Control, ASQ Statistics Division, Quality Press, Milwaukee, WI (1996).
5. Moore, D.S. (1990). "Uncertainty" in *On the Shoulders of Giants: New Approach to Numeracy*, L.A. Steen(Ed), National Academy Press, 95-137.
6. Snee, R. D. (1990). "Statistical Thinking and Its Contribution to Total Quality." *The American Statistician*, 44(2): 116-121.
7. Snee, R.D. (1999). "Discussion: Development and Use of Statistical Thinking: A new Era", *International Statistical Review*, 67(3), 255-258.
8. Wild, C.J. and Pfannkuch, M. (1999). "Statistical Thinking in Empirical Enquiry", *International Statistical Review*, 67(3), 223-265.