

## *Teaching through Inquiry: A Case-Based Approach*

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### **Abstract**

Case study method has been used rather widely in Universities across the world. The literature has also reported widely on the merit of using case study approach. Through the use of real data, and providing real life examples to contextualize textbook concepts, case method approach aims to help students develop skills in concept application through discussing complex real-life examples. While prevalently used in Business courses, it is less often used in other disciplinary courses such as Mathematics or Statistics. Currently, in statistical courses conducted in Singapore, from primary to tertiary education, contrived data using discrete examples (often from textbooks) are used for teaching. Students are expected to sustain their learning and interest through monotonous building-bloc statistical concepts. The teaching activities are also calculation driven without bringing real world meaning and applications into practice. As a result, students are less likely to appreciate the relevance of real world applications in statistical calculations. This paper looks at the possibility of teaching statistics through using authentic and meaningful case examples and approach. The advantage of such an approach is that it is able to develop active learning amongst students which in turn leads to better application of concepts taught.

Keywords: Case-based teaching, Mathematics

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## **Introduction**

*Case study method* has been used rather widely in most Universities around the world. Its merit has also reported widely (Dunne and Brooks, 1994; Kerber, 2001; Kruntz&Hessler, 1998 and Lundeberg, 1993). Using real data, and real life examples to contextualize abstract concepts, case method approach aims to help students develop skills in statistical concept application (Kerber, 2001; Kruntz&Hessler, 1998).

While prevalently used in Business courses (eg. Bruns, 1993; Christensen, 1981; Erkskine et al., 1981 and Shapiro, 1984) it is less often used in Statistics. More often than not, contrived data using discrete textbook-based examples are used for teaching. Through monotonous “building-block” statistical concepts, students are then expected to sustain their learning interest. Given that the teaching activities are calculation driven without bringing real world meaning and applications into practice, students are less likely to appreciate the relevance of real world applications in statistical calculations.

With the increased use of statistical analysis to unravel complex data found these days, educators realise the need to develop in students sound conceptual knowledge of statistics and competency to apply these concepts appropriately in different contexts. According to Gattuso & Ottaviani (2011), globalization has led to a new perceived complexity in the teaching of statistics, shifting from content knowledge to competencies. This paper therefore discusses a case-based inquiry approach for developing statistical reasoning and competencies. The advantage of such an approach is that it is able to develop active statistical reasoning through application of concepts taught (Dunne and Brooks, 2004, Hammond 2002, Richards et al., 1995).

### **Why is there a need to adopt a case-based approach?**

There is a growing recognition that we need to change the way we teach undergraduate statistics. Many introductory statistics courses tend to be taught through lectures. As a result, students do not always benefit as much as they ought to. Cobb (1991) in his treatise, *Teaching Statistics: More Data, Less Lecturing*, lamented “lectures don't work nearly as well as many of us would like to think”. According to him, if students do not understand statistical concepts, there is little value in knowing procedures.

Unfortunately, there is still an ingrained tradition perception of statistics as a discipline that relies solely on formulae and procedures. As a result, there have been calls to move away from this traditional notion, and to focus on students’ understanding of statistics, its use and its value.

The literature is replete with examples of student not acquiring sufficient understanding of basic statistical concept and not able to engage in statistical reasoning or apply concepts taught. Our experience, along with most faculty members, also seem to suggest that a large proportion of university students, do not appreciate many of the statistical concepts they are studying. Students, in general, often appear eager to try out the computational formula or procedure without internally having conceived a representation of the statistical problem. While they

may be able to memorise the formulas, and follow the steps given, they seldom appear to understand the rationale or how these concepts can be applied in new situations. Unfortunately, without conceptual understanding, students could easily misuse or misapply the procedures and formulas they memorised.

According to Scheaffer (2006), developing statistical thinking or reasoning is just as important, if not more important, than statistical knowledge. Statistical reasoning, essential to the 21<sup>st</sup> century society, should be the core focus in Mathematics curricula. We are proposing that statistical reasoning could be developed through the case-based inquiry approach. This is also in line with the call for using authentic, real world problems context for the teaching of statistics, as recommended in the Guidelines for Assessment and Instruction in Statistics Education (GAISE, 2005).

### **The Case-based Approach**

Current method to the teaching of statistics is contrived and ineffective in connecting learners to real world issues. To engage in statistical reasoning, teaching needs to be contextualized on real cases, bringing relevance and meaning to statistical data. Case inquiry here addresses ill-structured problems, where the problem statement, or statistical solution, lacks clarity or require negotiation. Through mathematical argumentation, reasoning, and hypothesis, case mathematical inquiry leads to fresh understandings, appreciation of complexities of given situations and ignites further questions for exploration (Magnusson & Palincsar, 2005).

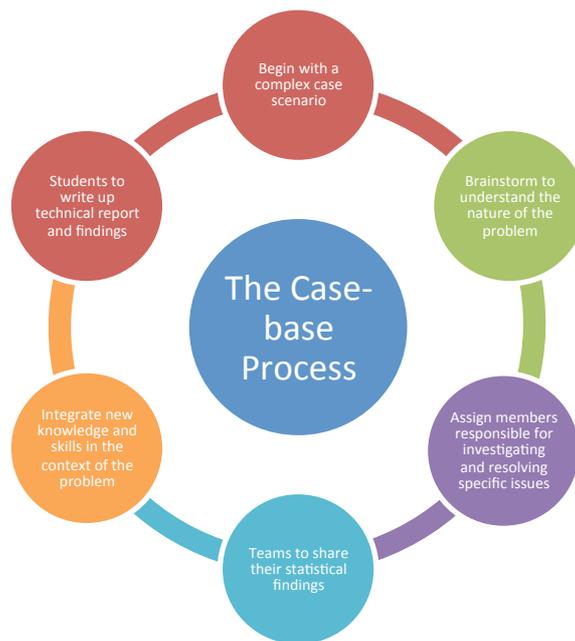
Supporting the case-based inquiry approach are researchers such as Nolan and Speed (1999) who have successfully developed and tried out courses using in-depth case studies. Created as a package, our proposed project will include:

- Interwoven real case examples with statistical data
- Learner notes with guided cues
- Instructor notes with guided instructions

Our proposed case study approach aims to bring meaning to statistical data through real case examples and applications. Students will learn the fundamental ideas of statistics in the context of current real world situations through cases presented. Through the project, students will:

- See the relevance of statistical concepts in the real world
- Gain confidence in the application of statistical concepts
- Develop the ability to develop a statistical solution in addressing real world problems or issues posed.

In our approach, statistics is taught as a laboratory science (Cobb, 1992). This approach is similarly used by Nolan & Speed (1999) who explored in depth a model for developing case studies/labs for the use of the undergraduate mathematical statistics class. Theory in a lecture format is first delivered to the students before the lab sessions. During the lab session, students are grouped and are presented the case. Figure 1 below describes the case inquiry process which takes place.



*Figure 1. Case-based Process*

Students are first provided an initial overview of the case and the statistical inquiry. They are to examine the sample, and data collected closely. Using the information given, students conduct relevant exploratory data analysis and test of assumptions. In groups, they interpret results within the context of the case, discuss findings and write up about the case findings.

In this process, tutors act as facilitators, and guide students in their investigations through questioning techniques and probes. In interacting with students, emphasis will be given to logical reasoning, mathematical thinking and proof. High level thinking skill questions such as ‘why?’, ‘how?’, ‘what if?’ are used in discussion. When developing the concept of covariation, for example, questions such as: “How do you describe the pattern in the data? Is there a positive linear pattern in the data? Can you generalise about the relationship from the sample to the population of students based on the data? Please provide your analysis” can be used. Likewise, when going through a case on fatality rate, the tutor could be asking: “Why couldn’t we use the mortality rate to describe the case fatality rate? What rule have you found?”, “Note that the daily incidence data are available in public websites but the detailed patient data are not. Can we make use of incidence data to obtain a better estimate or even a forecast of the case fatality rate? Why so and why not?”

In our proposed model, questions such as “Why?”, “How?”, “What if?”, “How do you know that?” are used to stimulate students to think critically and to make use of logical deduction. Such questioning approach emphasises mathematical reasoning and promotes much verbal discussion and interaction between the tutors and students as well as amongst the students themselves.

Through such active exploration and inquiry process, students pick up the different aspects and extensions of the statistics and probability concepts. At the same time,

they are also given the opportunity to use software tools to support their statistical calculations. Finally, they learn to report their findings in proper written format

### **Developing the Teaching Case**

Acquiring materials for the teaching cases might not be an easy task. However, within the discipline of Business and Operations Management, several case studies books focusing on statistics topics could be found. These include those by Bodily, Carraway, Frey, and Pfeifer (1996), and Lapin and Whisler (1996). The cases involve a range of topics such as inventory, queuing, simulation, and transportation and could include statistical topics such as regression and forecasting. Those teaching integrated quantitative methods course will find these cases useful.

Other than case studies books, a number of traditional textbooks also contain short statistical cases, more appropriate for introductory statistics courses. Among many others, such textbooks include those of Levine, Ramsey, and Berenson (1995) and Siegel (1997). More authentic cases could be collected through case reporting in research journals. An example is the Severe Acute Respiratory Syndrome (SARS) reported by Koh, Plant, & Eng (2003). Ideally, each teaching case should include the following:

- Clear scientific question presented in the context of the problem
- Background information of the problem
- Description of the data collected
- Required investigation

In the example of the Severe Acute Respiratory Syndrome (SARS), statistical data from a total of 8,096 cases reported globally (including those from Singapore) were collected. Examples of such authentic cases taken from local context provide interesting points of statistical investigation and discussion. To add realism, Yu, Chan and Fung (2006) suggested that students could assume the role of the consultant, statistician, policy officer or even data analyst to investigate the case questions. Student could also go on to discuss on the role of statistics in fighting against SARS (Koh, Plant, & Eng (2003).

### **The Use of Technology**

Technology should be accessible for the students. Instructors these days have the choice of selecting between a number of quality statistical software packages; SAS (<http://www.sas.com>), MINITAB (<http://www.minitab.com>), SPSS (<http://www.spss.com>), R (<http://www.rproject.org>), etc. Continuing upgrades of the software has led to menu-driven packages making it easy for the student.

Also available is Excel which could be used for easy computations. In the recent years there is a tremendous growth in the development of applets. Applet is also another tool to help students visualize the statistical concepts. Supporting the use of the tools is also the availability of the text books on technology commands and instructions.

Depending on the course learning outcomes, instructors should seek appropriate technology necessary to meet the learning goals of the statistic course. It is important to be able to provide allocate sufficient computer time for the course structure. The

other consideration is the level and need of students for the software and the licensing costing. In the lab based class discussed in this paper, we use Excel for simple statistical analysis as the students have easy access, and SPSS for the more complex statistical calculation and analysis.

### **Value of this Approach**

Inquiry is relatively uncommon in statistics teaching using well-structured and context free problems. As a result, students in statistics may lack confidence to deal with uncertainties that arise. Therefore, initial experiences can be especially daunting (Anderson, 2002; Makar, 2010). Nonetheless, there is value in this approach once students overcome their fear and lack of confidence.

First of all, students gain practical experience and ability to apply theoretical concepts. This approach follows closely to what a statistician might do in reality. Rather than a straightforward and linear approach, the investigative process requires backtracking and revision as new findings emerge. As cases are authentic and have depth, the approach generates interest, and strengthens problem solving skills. Learning by cases also provides students the means to experience working with real data and statistical inquiry, and acquire some independent thinking. They examine the case, conduct their own analysis and make recommendations based on what they found. They also have the opportunity to compare what they did to what statistician did in the actual case study.

Secondly, students also learn to make errors in safe and secure environment. In this approach, the consequences of errors are fairly benign. Students do not lose credibility, or to live with the full consequences of their analysis. Our experience with our students show that they learned from others' contributions and strengthened their understanding. A further benefit of learning by the case approach is the opportunity to acquire experience mimicking what they might find in the real work environment. Thirdly, we would like to suggest that this approach is useful to developing transferable skills such as the following:

- *Practical skills.* Case studies might involve practical work and hands-on approach to conduct statistical analysis.
- *Information gathering and analysis.* Case studies require students to utilise a number of different sources (e.g. Internet, library and experts) for resource investigation,
- *Individual study skills.* Case studies encourages students to be self-directed learner and carry out independent research outside of the lecture/tutorial environment.
- *Group working.* Student benefit from learning to work with one another.
- *Presentation skills.* Students pick up presentation skills using a variety of formats, such as oral presentations, posters and reports.
- *Time management.* Students learn to manage time as they consider how best to carry out the tasks to be completed to the set deadline.

Finally, cases impart reality. In our work with students, students report increased confidence in their ability to apply statistical methods in the workplace, and to

communicate their findings to stakeholders through studying authentic cases. There is value in the use of the case-based approach to developing lifeskills.

### **Conclusion**

This paper focuses on the teaching of statistics using inquiry case-based approach. Statistical teaching is successful insofar it moves away from the focus on formulae and procedures to statistical reasoning and thinking. Our proposed inquiry case-based approach is an approach to develop this statistical reasoning and thinking. Only through getting students involved in active analysis of real data do they see the relevance of statistics in the real world and appreciate the value of statistical concepts taught.

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