Incorporating Statistical Consulting Case Studies in Introductory Time Series Courses

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Established as a rigorous pedagogical device at Harvard University, the case method has grown into an indispensable mode of instruction at many business schools. Its effectiveness has been praised for increasing student participation during in-class discussions, providing hands-on engagement in real-world business problems, and increasing long-term retention rates. This article illustrates how novel case studies that mimic real-life statistical consulting engagements can be incorporated in the curriculum of an undergraduate, introductory time series course. The assessment of learning objectives as well as pedagogical implications when teaching using statistical consulting case studies is elucidated. The article also lays out guidelines for adopting statistical consulting case studies should the readers choose to incorporate the case method into the curricula of courses that they teach. A sample case study which the author has successfully used in his classroom instruction is provided in this article.

KEY WORDS: ASA guidelines; Bloom's taxonomy; Business forecasting; Entrepreneurship education; Experiential learning; Model building; Statistical education.

1. INTRODUCTION

In the conference titled "Making Statistics More Effective in Schools of Business" held at the Graduate School of Business at the University of Chicago in June of 1986 it was unanimously stressed that more case studies in business statistics were needed. In particular, the task force consisting of prominent academic and industrial statisticians, which was responsible for the examination of the pedagogical approach of time series and forecasting instruction at business schools, had arrived at the following conclusion:

> The group agreed that it is highly desirable to spend time on cases in business forecasting. In a forecasting case as opposed to a forecasting example, the forecasting problem is set in its business context. One should know why forecasts are required, what data are available, what is the quality of the data, and what knowledge of the data-generating mechanism is accessible. All participants agreed that the greatest contribution to teaching of forecasting would probably be development of good forecasting cases. It would be especially attractive to have cases in which nonroutine application of forecasting methods is required (Easton et al. 1988).

There are different viewpoints as to what qualifies as a "statistical case" but by and large, "a case should include a dataset and documentation on how data were obtained, discussion of the business problem that might be illuminated by intelligent analysis of data, and at least a little background on the business situation" (Easton et al. 1988). The case method may be tracked back to Ancient Greece, originating in the dialectic method of Socrates (Valaitis and Gray 2006). Socratic dialogs, as descended to us from the writings of Plato and Xenophon, describe the nature of Socratic Method as a discussion between two or more conversationalists, who generally hold differing points of view regarding the topic of discussion, but attempt to uncover the truth using judicious arguments.

The inquiry of the origins behind the modern use of the case method takes us back to only the end of the 19th century (Carter and Unklesbay 1989; Merseth 1991; Valaitis and Gray 2006), reaching dean Christopher Columbus Langdell of Harvard Law School (HLS), who in 1870 stressed the importance of practical case discussions for teaching jurisprudence. The aim of the method, as established by HLS, was rooted in generalizing decisions for gaining a broader comprehension of principles of law (Merseth 1991). Roughly four decades after dean Langdell introduced the case method in HLS, the popularity of the method was spread to the business instruction with the appointment of Wallace B. Donham in 1919 as the dean of the Harvard Business School. According to him, it was the problem-centered approach anchored in real-life situations that needed to be the stressed in business curricula (Merseth 1991).

Despite the added benefits of the case method, the practical adoption of case teaching by statistics educators has been somewhat lukewarm (Parr and Smith 1998). On the other hand, the majority of case studies in statistics that were found in literature lacked the sophistication of real-world business problems. This article responds to the necessity for case studies in time series and forecasting. More specifically, based on a literature review the article will first illustrate the numerous benefits of using case studies when teaching statistics. Subsequently, drawing on author's experiences with designing and administering time series case studies, a particular type

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of a case study namely, a consulting-style case study, will be thoroughly described, meticulously exemplified, and assessed. The article will also provide detailed guidelines for using such case studies, should the interested educators decide to adopt the method in their undergraduate time series courses.

The rest of the article is organized as follows. The use of the case method as a mode of undergraduate statistics instruction is surveyed and reviewed in Section 2. Section 3 describes statistical consulting case studies and provides detailed guidelines on how to incorporate such case studies in an introductory time series course. Subsequently, section 4 evaluates the learning objectives and provides pedagogical implications when teaching using statistical consulting case studies. Section 5 describes a sample statistical consulting case study that the author has implemented in an introductory, undergraduate time series course. Finally, section 6 provides a further discussion of statistical consulting case studies and their role in broader undergraduate statistics curriculum, and concludes the article.

2. REVIEW OF THE CASE METHOD

The conventional lecture-based teaching format, as compared to more active learning, presumes that students are relatively passive participants; that is, the main in-class expectations of students are those of a listener and note-taker (Hakeem 2001). Researchers have emphasized the drawbacks of passive-learning environment in that due to the very nature of the setting, while the students are exposed to the delivered information, they are rarely given the opportunity to process it adequately (Shakarian 1995). The deep and active processing of consumed information, which is responsible for accurately recalling the information later, is contingent upon students carefully examining the concepts that they are presented, as well as relating to and reflecting on those (Shakarian 1995). This viewpoint resonates well with the Constructivist learning theory, according to which the genuine understanding occurs only after the learner has built his/her own interpretation of the material being taught, thus personally attaching own meaning to the information (Garfield and Ahlgren 1988; Valaitis and Gray 2006). But in the traditional lecture-based environment, as students constantly attempt to juggle two competing tasks of listening to the instructor and taking notes simultaneously, the level of their concentration diminishes. According to memory research among medical students (Stuart and Rutherford 1978; Penner 1984; Shakarian 1995) students could concentrate the best during the first 10–15 minutes of the lecture after which their attention sharply deteriorates until the very last few minutes of the lecture. Consequently the effectiveness of solely lecture-based instruction is questionable.

Researchers have repeatedly stressed the importance of the experiential learning approach for statistics instruction, and emphasized its benefits as compared to the traditional lecture-based instruction. The knowledge gained in the course of experiential learning, according to Snee (1993) can be attributed to working with real datasets, as well as to solving real problems and improving processes. As opposed to passive learning, Cobb (1991) placed experiential learning in the active learning category, while Hakeem (2001) noted that active learning requires students to apply the theory learned during the lecture to real-life situations and engage in higher order of thinking. Among the many researchers who have advocated the experiential learning approach for statistics instruction are Smith (1998), Johnson and Dasgupta (2005), Hillmer (1996), Keeler and Steinhorst (1995), and Cobb (1991).

For the creation of an experiential learning atmosphere many researchers have stressed the effectiveness of projects and case studies, which enable students to engage in the learning process by talking, listening, reading, writing, and reflecting (Meyers and Jones 1993). Hakeem (2001) studied the effectiveness of a semester-long experiential learning project where students participated in the collection and statistical analysis of the data, as well as in the preparation of a written report detailing the analyses. The author documents significant increase in both students' average examination scores and the percentage of students who performed at a C level or above, as compared to a control group. Pariseau and Kezim (2007) conducted a controlled study to assess the effectiveness of open-ended collaborative case studies, consisting of both an analysis and a written deliverable component, in an introductory business statistics course. The authors report that on the problem portion of the comprehensive final examination, on average, the students who throughout the semester have completed case studies significantly outperformed those who were not taught with case studies. In addition, students who conducted a case study expressed more positive attitude towards the subject of statistics. Student retention rates in an introductory engineering statistics course, where student teams completed projects during a 10-week class and were compared to a control group, were studied by Kvam (2000). According to the author, the results of the study indicated that compared to students who had not participated in projects, those who had completed the projects on average demonstrated higher retention rates of the studied material when evaluated towards the end of the course and then again eight months later.

The advocacy for statistical case studies has been generally based on the following three reasons: cases result in longer retention of statistical concepts; cases improve collaboration, teamwork, and the communication of results, all of which are valued skills at the workplace; and cases enable students to integrate quantitative skills into business decision making. Additionally, it has been noted that cases enable students to appreciate the entire process of statistical inquiry as opposed to isolated calculations that are only one part of data analysis (Parr and Smith 1998). Cases may also provide students with a more real-like datasets, which can be messy due to missing data, outliers, redundant/irrelevant data, and multiple data sources to work with. It has also been noted, that cases enable students to appreciate the research aspect inherent in many statistical engagements but not necessarily present in standard textbook exercises (Valaitis and Gray 2006).

The literature review including both peer-reviewed and non-peer-reviewed journals, as well as textbooks on time series and forecasting did not uncover many case studies in time series that would satisfy the characteristics listed above. First, the found case studies were based on data which had already been summarized and cleaned, and were thus devoid of any issues such as missing values, outliers, duplicates or any raw data in need of organization and tabulation before being modeled. In addition, none of the datasets accompanying those case studies included variables in text format, which would necessitate meticulous processing of textual information by students. That is not in line with the way real data appear in the repositories of business organizations. Indeed, data very often are scattered over multiple repositories and contain numerous outlying, missing, as well as redundant or irrelevant data values, thus requiring a meticulous data preparation and cleaning. Also, in this age of big data it is not infrequent for datasets to contain textual information that needs to be carefully accounted for prior to any statistical inference. Second, the existing cases did not leave enough wiggle room for students to exercise their own creativity in finding solutions to the postulated business problems. Instead, the cases often explicitly spoon-fed specific technical tasks that needed to be performed by students, such as fitting a particular model or calculating sums of squares, thus minimizing independent inquiry and research. Third, the cases did not demand serious consulting activity from students. Relatedly, those cases did not require genuine collaboration and teamwork, nor did they imply an inquiry-based fact-finding through discussions and meetings, which is what true statistical consulting engagements are based on. Fourth, many of the reviewed case studies did not require a deliverable business presentation (pitch) of the results, thus overlooking the importance of clear communication of technical material in nontechnical language, as well as missing the task of marketing the final deliverable product of the case study. Fifth, and from the technical standpoint, the cases found in the majority of textbooks did not entail iterative model building that is at the core of time series modeling. Indeed, the cases often lacked the full cycle of tentative identification, fitting, and checking of various time series models with the aim of arriving at the one(s) providing the best predictive power. Additionally, there was often no model validation and evaluation component present in those cases.

In summary, the found case studies were simplistic to represent real-world problems that call for statistical solutions. Quantitative problems occurring in practice and the contextual settings in which those appear are considerably less clear-cut.

3. STATISTICAL CONSULTING CASE STUDIES

My approach to case studies in time series stems from the shortcomings of the existing cases found in literature, and is based on the general characteristics that a successful case study should possess. The case studies that I have designed and taught with, were administered as mini consulting projects, with me assuming the role of the "client," meeting with the engagement teams during the scheduled status update meetings and elucidating all the questions that those teams might have.

I hasten to stress that the idea of injecting a consulting flavor into a case study has been elegantly applied in other quantitative disciplines. For example, the uses of consulting-style case studies in undergraduate technology and operations management class have been proposed and described recently by Erzurumlu and Rollag (2013). At the same time, in business statistics curricula the use of consulting-style case studies that use messy data, pose nonstandard business problems, require independent research as well as fact-finding during the periodic status update meetings with the instructor, and involve a marketing aspect through a business pitch of the deliverable product, has not yet been documented in literature.

3.1 Description and Objectives of the Approach

Any pedagogical approach is based on the objectives that it aims to satisfy. Formulated as teaching objectives, the goals of my approach are to:

1. Expose students to real-life business problems that involve messy time series including missing values, outliers, duplicates, text entries, as well as raw (unorganized) data.
2. Accustom students to working under uncertainty, involving nonstandard problems requiring independent research and investigation prior to statistical modeling.
3. Impart the mindset that a statistical consulting engagement is a spectrum ranging from data acquisition and data preparation (cleaning) to modeling, generation of the necessary written deliverables, and presentation (pitch) of findings, at each stage requiring effective communication with the client.
4. Enhance students' communication and presentation skills of quantitative material to an audience consisting of both technical and nontechnical members.
5. Train students in iterative model building of time series models from tentative model identification to fitting/checking and evaluation of the selected time series models.

The case studies that I have developed and administered were all different in business application and data structure. Nonetheless, all shared the same general scope. In particular, the case studies were based on the following generic scenario:

> Company X is outsourcing the development of a data-analytic tool that is sought for improving its business operations. You and your team have submitted a proposal for a pilot-study and have been notified that you are awarded the contract. Now is the time to develop the product that your client (Company X) is looking for and to deliver it in a way that will convince your client of the effectiveness of your solution and of its relevance to their business problem. You have the unique opportunity to help your client attain the next level of business intelligence and become capable of competing on the grounds of data analytics.

In a nutshell, my case studies parallel the research and development effort of a new product, which in this case is a predictive model. Teams conducting the case studies are akin to designers and builders of a new product which they iteratively assess and enhance throughout the engagement. To arrive at the final product, students use the learned quantitative reasoning, modeling, and forecasting skills taught to them during the semester through more traditional instruction methods (e.g., lectures or mini-lectures). But that is only part of the expectation from students, and that is where it gets interesting. In particular, these case studies are set up as small-scale consulting engagements where the instructor serves as "the client" and periodically meets with students during the entire course of the engagement. At the engagement kick-off, students are notified that there are many data-related details and subtleties which are deliberately left out from the cases that they receive, and one of the key expectations from students is that in the course of the engagement they are required to ferret out those nuances through carefully thought and well-formulated inquiries. For that reason, the instructor schedules weekly or bi-weekly status update meetings with each team to provide students with the opportunity to update the instructor with their progress and to engage in fact-finding inquiries, thus resolving any roadblocks that they encounter.

Noticeably, the case studies designed and formatted in this way possess a very strong consulting flavor. First, unlike many projects and case studies, where a team is assigned a problem and reports back at the final team presentation, the case studies, because of the required periodic status updates initiate an ongoing dialog between the students and the instructor/client, during which students get the opportunity to ask the questions that a consultant would ask during consulting engagement with a client organization. Such questions include but are not limited to those pertaining to the business processes generating the data, the data quality (e.g., the nature of missing values and outliers), and to additional data sources to be used for modeling. Second, rather than being narrowly focused technical exercises, my case studies instead encompass a gamut of tasks ranging from data preparation to business research and presentations. Third, similar to many real consulting engagements, students do not have the option to pick and choose who they are more comfortable working with. Instead, at the engagement kick-off students are assigned to teams per instructor's discretion. Fourth, the case studies necessitate effective team collaboration throughout the entire course of the engagement, which in turn demands clear and effective communication skills both with the instructor/client and among team members. All of the above mentioned attributes parallel the time series case studies that I have designed and administered to real-life consulting engagements. Thus, throughout the rest of this article I will refer to those as *statistical consulting case studies*.

3.2 Administration of Statistical Consulting Case Studies

At Babson College I have taught an introductory, undergraduate time series and forecasting course using statistical consulting case studies that I had developed. The class consisted of 27 students, the vast majority of whom were seniors with good knowledge of Microsoft Excel and Minitab and a solid background in elementary statistics concepts such as descriptive statistics, confidence intervals, hypothesis testing, and linear regression analysis. In my class, prior to engaging in case studies, students had learned time series topics such as autocorrelation, exponential smoothing, seasonality, autoregressive integrated moving average (ARIMA) models, iterative model building, and time-series transformations through lectures or mini-lectures followed by in-class, hands-on forecasting "sessions." Note that the above mentioned qualifications are prerequisite for a successful completion of the statistical consulting case studies described and discussed in this article. Additional familiarity with statistical programming languages such as R or SAS would be desirable albeit not required. It should be also mentioned that based on both in-class participation and performance on major grading components of the course, the students in my class were highly motivated and quantitatively oriented.

Following are a few important details regarding the implementation of the case studies. On the day when the case studies were assigned, I split the class into teams consisting of five–six students. Based on randomization performed in class, each team received a unique case study designed and written by me, together with the accompanying dataset. Subsequently, the teams were informed of the dates when the final team presentations would be due, which were approximately one month from the day when the case studies were assigned. Further, students were notified that significant details regarding inconsistencies appearing in the data files were deliberately left out from the distributed cases, and that the uncovering of those details during the status update meetings was one of the key expectations from students. Afterwards, the schedule of the status update meetings was agreed upon with each team based on student availability. Teams were notified that they had to internally determine on how to split the tasks among team members, and who would present what during the final presentation. A deadline was set for notifying me (via email) the exact task that each member would be responsible for. For six-member engagement teams the breakdown of student responsibilities during the presentation had to adhere to the format laid out in Figure 1. As for the five-member teams, the format of the roles was similar to that of six-member teams, with the exception that there would be one less model developed. Note that, regardless of the team size, the responsibility that each member assumed for the final presentation had to match the responsibility that he/she would have throughout the engagement.

One of the advantages of the statistical consulting case studies over the traditional case studies is that they demand effective teamwork and collaboration. Right from the kick-off, it was made very clear that throughout the entire engagement the team members were expected to collaborate. Rather than solely focusing on individual tasks, each student was expected to take full ownership of the case study and add his/her contribution in all stages of the engagement. To increase the likelihood that the students within each team would in fact collaborate, several strategies were instituted. First, it was emphasized that collaboration was in the best interest of each team member and that at the end of the case study the students would be required to complete peer evaluations assessing the effectiveness of their team members as collaborators. Second, students were informed that each team member would be receiving the same grade for the technical deliverable report based on the depth of the analysis and the effectiveness of the forecasting methods described in the report. Third, notice that the breakdown of responsibilities displayed in Figure 1 reinforces the need for team members to collaborate and take active role in their peers' work streams. For instance, while the four Data Analysts were responsible for modeling of data and not the data preparation that the Data Manager was accountable for, it was nonetheless in their best interest to assist the Data Manager in accurately preparing the data, since the models would be based on inaccurate data, otherwise. Similarly, while the Project Manager set the stage for the presentation through the introduction and was not immediately responsible for the technical side of the engagement, in reality the Project Manager needed to have a solid understanding of the technical subtleties of the engagement since he/she would also

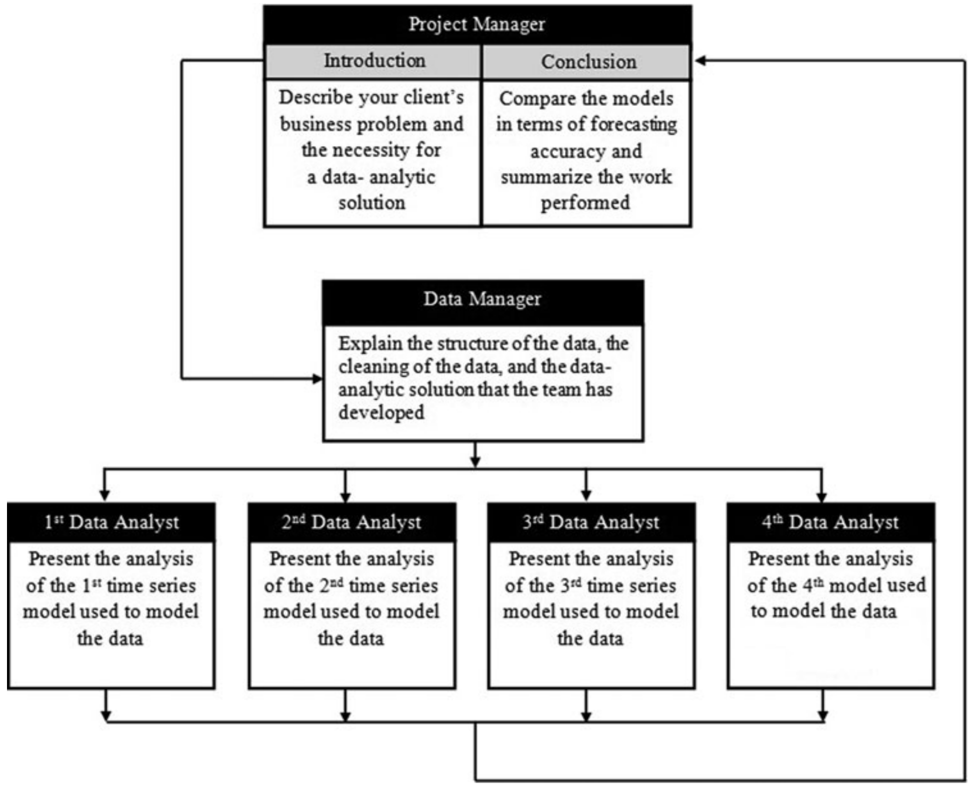

Figure 1. Breakdown of responsibilities for a six-member engagement team.

conclude the presentation by carefully comparing the models and selecting the one(s) providing the best predictive power.

Each student's grade was determined as a weighted average of his/her grades received for the presentation to the class, written deliverable report, submitted, and received peer evaluations. Note that as previously indicated, for the written deliverable each team member received the same grade. On the other hand, the grade received for the presentation component was student-specific and was based on the overall soundness of the presented content, the ability to effectively address the instructor's questions, as well as the student's presentation and communication skills.

The time that instructors might commit to administering statistical consulting case studies deserves a special note. To kick-off the project season, instructor would typically dedicate up to an entire lecture, meticulously going over her/his expectations, deliverables, group assignment, and the grading model for the project. Afterwards, the main touch points with the engagement teams are in the form of status update meetings. These meetings can be weekly or bi-weekly, each ranging roughly from 20 minutes to several hours, depending on the time that the instructor and the teams are willing to commit, complexity of data in the case studies, the sizes of the teams, as well as how much of the information is intentionally kept out from the formulations of case studies and assumed to be exposed during those meetings. Notice that either per teams' request or by instructor's choice, additional follow-up meetings can be scheduled throughout the engagement, especially in case the instructor wishes to more closely monitor the progress of the teams. Further, based on my experience the presentations for five- and six-member teams lasted roughly 30 and 35 minutes respectively. Of course this time can be altered by limiting or extending the time set for individual presenters as explained in the instructions that students receive during the engagement kick-off.

4. ASSESSMENT OF LEARNING OBJECTIVES AND PEDAGOGICAL IMPLICATIONS

4.1 Evaluation of the Approach Using Bloom's Taxonomy

Certain pedagogical approaches suit specific learning objectives. One of the limitations of the traditional lecture-based instruction is that while it promotes lower-level skills such as recollection of the material from memory and comprehension, it is not as effective in attaining higher-level objectives such as analysis, synthesis, or evaluation of the material (Lovell-Troy 1989). In order to hypothetically assess statistical consulting case studies, it is important to understand what learning objectives such case studies satisfy and how those objectives relate to the depth of understanding of the material being taught. A formal hierarchy of learning objectives was proposed in 1956 by Bloom, Engelhart, Furst, Hill, and Kratwohl. Bloom's *Taxonomy of Educational Objectives* (Bloom et al. 1956) is a well-established classification system for cognitive educational objectives. The taxonomy is hierarchical in that the achievement of the learning objectives at higher levels is contingent upon successful attainment of objectives at lower levels of the taxonomy. The six building blocks of the taxonomy in the hierarchical order from lowest to highest are knowledge, comprehension, application, analysis, synthesis, and evaluation.

Unlike traditional lecture-based instruction which satisfies the lower-level elements of Bloom's taxonomy such as knowledge and comprehension, the learning objectives inherent in statistical consulting case studies tie with those situated higher in the taxonomy. Indeed, while well-organized lectures have the potential to effectively enhance student's knowledge and comprehension of discipline's core concepts such as autocorrelation, seasonality, transformations, smoothing methods, ARIMA modeling, and in addition hypothetically demonstrate what a statistical consulting engagement is like, for a more in-depth and especially hands-on understanding of those topics, as well as for experiencing the entire depth and breadth of a statistical consulting engagement, statistical consulting case study is a handy pedagogical device to use. To illustrate, when exposing a student to real-life business problems that involve messy time series, a student is expected to discover that for instance Holt's method that he/she was taught during a particular lecture as a smoothing approach, is a convenient method to use also for data imputation. Thus the learning objective that is being met in Bloom's taxonomy is *application*. Moreover, in order to recognize and accurately classify the data inconsistencies such as outliers and missing values, students first need to carefully *analyze* those inconsistencies. On the other hand, experiencing statistical consulting engagements as a range of activities from data acquisition to delivery, students are able to *synthesize* different bits and pieces of the spectrum that they had been exposed to during the lecture-based instruction. Further, during the team presentations, students are required to assess the predictive power of their best model(s) by comparing and contrasting with other models that they have entertained. Consequently, the presentation enables students to critically approach the model building by *evaluating* the product that they have built during the engagement. In addition, presentation provides students with the opportunity to learn to *synthesize* only the most relevant and noteworthy findings of their work, in order to craft the storyline underlying the findings and to effectively market their final product to the client. Displayed in Table 1 is the summary of statistical consulting case studies, mapped onto the elements of Bloom's taxonomy.

The value added by teaching time series using statistical consulting case studies makes them effective tools for not only exposing students to practical problems that appear in real world, but also for ensuring a deeper understanding of time series concepts and thus a longer retention of such concepts in memory. It is important to note that the described advantages are also independent of the field of study in which time series is being taught. Indeed, notice that the above exposition does not rest on any assumptions about the academic discipline or a school of study offering the introductory time series course. Time series instruction using statistical consulting case studies is potent to bear fruit irrespective of whether the course is being taught in, for instance a school of education, public health, or arts and sciences. What follows is an implication of case teaching in business administration, with a focus on entrepreneurship education.

Table 1. The relationship between the learning objectives of statistical consulting case studies and the elements of Bloom's Taxonomy

Learning objective of a statistical consulting case study	Corresponding element in Bloom's taxonomy
Exposing students to real-life business problems with messy time series	Application; Analysis
Accustoming students to working under uncertainty	Application; Analysis; Synthesis
Imparting the mindset that a statistical consulting engagement is a spectrum	Synthesis
Enhancing students' communication and presentation skills	Synthesis; Evaluation
Training students in iterative model building of (time series) models	Application; Analysis; Synthesis; Evaluation

4.2 Implications for Entrepreneurship Education

Statistical consulting case studies conveniently fit into the learning framework established for entrepreneurial education. Indeed, it has been well documented that entrepreneurship majors (budding entrepreneurs) in undergraduate institutions possess distinctive personality factors that are vastly different from those manifested both in non-entrepreneurship majors and in non-business majors. In particular Sexton and Bowman (1983) conducted a study of 401 Baylor University undergraduates to determine the personality factors for several distinct student bodies. What the authors found was that entrepreneurship majors differed from the rest of the students by their autonomy, ability to adapt to change, and risk averseness, among several other factors, evaluated using the Jackson Personality Inventory (JPI) and the Personality Research Form-E (PRF-E). Based on their research authors concluded that entrepreneurship students hold a unique profile that is unlike any other student segment both within the business school and outside. Particularly, entrepreneurship students are more autonomous, welcome change, are capable of original thought, and navigate well under uncertainty (Sexton and Upton 1987). An important conclusion that the authors drew as a result was that entrepreneurship courses should be unstructured and contain problems that necessitate unique approaches and elegant solutions rather than routine applications of existing methods. Another important educational takeaway that the authors emphasized was that the entrepreneurship education should pose a "frustration factor," which for instance might take the form of incomplete data and serve as a potential hindrance for project completion. Sexton and Upton (1987) as well as Ronstadt (1983) attested that a successful entrepreneurship program should be designed in a way that familiarizes students with the barriers hindering the initiation of new business ventures. Only then, according to the authors, could students come up with ways to overcome those barriers. Additionally, according to Robinson (1996), entrepreneurship education is heavily geared towards bolstering the cognitive and analytical skillset of aspiring entrepreneurs with only a light emphasis on affective and conative abilities. Nevertheless, according to the author, the latter skills should not be overlooked since "The tension, existing at the chaotic ambiguous early stages of a venture, is manifest in ways such as (a) the excitement involved in the identification, evaluation, and the pursuit of opportunities; (b) the anxiety associated with critical decisions about strategy and execution; and (c) the deep personal involvement with and commitment to the business concept or product" (Robinson et al. 1993).

In the statistical consulting case studies, the data issues in the form of missing, outlying, irrelevant, text, and raw data, as well as the ill-defined nature of the problems inherent in those case studies uniquely qualify to what Sexton and Upton (1987) referred to as "frustration factor" that requires the ability to operate under uncertainty and demands competence to find nonstandard solutions. No ready-made models or conventional solutions are available to students for overcoming those barriers, and students are expected to arrive at their own solutions through skillfully leveraging the technical artillery that they have been exposed to during the semester, as well as through effective communication with the instructor/client.

When teaching with statistical consulting case studies, I have observed students welcoming the uncertainties and challenges. Moreover, the model building activity iterating between identification/fitting and residual checking cultivates the conative and affective abilities mentioned by Robinson et al. (1993) and Robinson (1996) since the above mentioned iteration by its very nature is a process of learning from mistakes. In turn, for one to be able to learn from mistakes, through each iteration one has to possess not only the technical adroitness to accurately spot the leftover noise structure represented by the residuals, but also demonstrate an emotional intelligence to not give up and constantly aim for model improvement. In addition, experiencing a statistical consulting engagement as a spectrum consisting of many intermingled and moving parts that feed into each other, is one of the biggest contributions of the consulting case studies, at least as important as the final predictive analytic solution. And this resonates well with what Robinson (1996) considered as the biggest takeaway of a successful experiential learning activity namely, "the processes involved in arriving at the solutions." It is interesting to note that this approach of generating nonstandard solutions is in line with an ongoing movement to reform management education from a deductive format, where students emulate others' solutions to an inductive format, which is based on an experiential learning setup where students learn by attempting various solutions and iteratively assessing the results (Bigelow 1995).

5. A SAMPLE STATISTICAL CONSULTING CASE STUDY

In this section I describe a statistical consulting case study which is similar to one that I assigned and administered in an introductory undergraduate time series and forecasting course taught at Babson College. A six-member team was assembled to conduct the case study. Actual case studies prepared by me and accompanied by teaching notes as well as data supplements can be purchased from the Babson Collection at the Case Centre, where those were published as part of the Entrepreneurial Leader Collection (*http://www.thecasecentre.org/*).

5.1 Brief Overview of Digital Billboards[1]

Digital billboards are the cutting-edge when it comes to highway advertising. Through digital technology, billboards display high definition imagery, offering unparalleled versatility to advertisers in marketing to wide audiences which were out of reach before. Digital billboards often alternate among commercials, by automatically changing the advertisements as frequently as every few seconds or as rarely as once or twice during the day. Equipped with light sensors which measure the amount of light reaching the billboard, digital billboards mechanically correct their brightness during the daylight and nightlight to ensure visibility.

It is not surprising that advertisers take full advantage of the flexibility offered by digital billboards. For instance, while eateries advertise breakfast commercials in the morning and dinner ads in the evening, real estate agencies leverage billboard technologies by featuring houses for sale only until the house gets sold, after which they change the content near-real time. Digital billboards are also used by the traditional print and broadcast news media to deliver headlines and weather updates. Law enforcement agencies also reap the benefits of digital billboards, since the latter enable them to reach mass audiences in a matter of seconds. For example, the photograph of a missing person may be displayed on a digital billboard as quickly as seconds after the person has gone missing.

In 2008, *Arbitron*, a media research firm conducted a survey focused on the Cleveland, OH metro area to find out public opinion regarding digital billboards. Digital billboards were a big hit especially among younger respondents. Based on the survey results, among the 18–34 year adults, 60% felt that digital billboards were attractive, and 86% agreed that digital billboards help communicating emergency information. Overall, 77% of the 18–34 year olds reported that digital billboards are an attractive way to advertise. According to Cleveland City councilman Joe Cimperman, "Digital billboards are right in line with the whole cityscape. They communicate that we are a city that embraces technology. We actually have some of the newest state-of-the-art, cutting edge advertising."

5.2 Business Background

Vespucci Advertising, an advertising startup has recently adopted billboard technologies and has just installed its first digital billboard on highway Interstate 80 (I-80). Among its advertisers are two local Midwest breweries, an organic grocery store chain, and an automobile insurance company. Vespucci charges its customers on a pay-per-use basis. Despite the impressive revenue figures generated from other forms of advertising, Vespucci's profit from the digital billboard on I-80 has been anything but attractive, and has even caused Fuminori (Fumi) Kitano, the CEO of Vespucci to seriously question the worthiness of the business venture. During the latest management meeting, Mr. Kitano engaged in a heated (but constructive) discussion with Ms. Namita Nair, the firm's Vice President (VP) of

[1]Source: About Digital Billboard Technology; *Outdoor Advertising Organization of America*.

operations, regarding whether the firm had been mispricing the time during which the broadcasts of the client advertisers are transmitted through Vespucci's billboards (also known as the "airtime"). After about an hour and half of focused exchange between the two, it was concluded that the firm might have to change its pricing scheme. Per minute of airtime, Vespucci has been charging the same flat rate ($3.31) to its customers regardless of the time of the day when the content is being aired. The flat rate was calculated based on an estimated volume of I-80 traffic that passed by the digital billboard in an hour. That estimate of hourly traffic was provisionally set at 7500 vehicles. For each vehicle that was expected to pass by the billboard in a 1-minute period, Vespucci would charge its customers 2.65 cents per minute of airtime. Consequently, for a minute of airtime the company would charge each of its customers the per-minute rate (2.65 cents) multiplied by the number of cars that were expected to pass by the billboard in 1-minute window (125 cars) which yields the current price of $3.31. And charging the same flat rate regardless of the time of the day/day of the week, seemed a little too naïve, according to Mr. Kitano.

Mr. Kitano delegated to Ms. Nair to reach out to Traffic Flow Technologies Ltd., a leading player in the collection of highway traffic data via radio frequency identification devices (RFID), to get a thorough understanding of the traffic flow on I-80. As Mr. Kitano explained to Ms. Nair, after the firm acquires the required data from Traffic Flow Technologies, Vespucci will need to seek out the help of management consulting houses in the area to assist Vespucci with the analysis of the traffic volume data, hoping that such insight can help Vespucci effectively modify the pricing scheme and thus generate thicker profit margins from the digital billboard advertising. In particular, Mr. Kitano is very enthusiastic about the prospects of dynamic pricing, where instead of having a rigid pricing scheme that is carved in stone, the price for airtime would synchronously change based on the expected incoming flow of traffic by the digital billboard.

5.3 The Assignment

You and your team submitted a proposal for a pilot-study with Vespucci Advertising and have recently been notified that you are being awarded the contract. Your team's task on this assignment is to find out how the current flat-rate pricing scheme can be improved in light of the traffic volume data collected from I-80 by Traffic Flow Technologies Ltd. To arrive at the solution, you are provided hourly data on the volume of traffic passing by the billboard, as detected by the RFID meter attached to the billboard on I-80. Unfortunately, the data are not well organized and have number of issues such as missing values, outliers, redundancies, and text entries. The data will be provided to your team separately as a Microsoft Excel file.

After the engagement kick-off, your team has to determine internally how to split the work among the team members, by choosing from the list of roles predefined by the instructor and provided to you as a separate document. Throughout the entire engagement, you are required to collaborate. Consequently, you are expected to not only attend to your own responsibilities but also to actively take part in those of your team members.

Two deliverables are sought by your client company: a presentation/pitch to management explaining the data-driven approach that your team will develop for improving the flat-rate pricing scheme; and a written report detailing your approach. Note, that each presenter will get five minutes for his/her pitch with the exception of the project manager who will both open up the presentation for five minutes and conclude it for another five minutes. Below are some of your client's expectations from the final presentation that you will deliver:

- Present the problem and stress the need for a data-analytic solution.
- Describe your team's approach to solve your client's business problem.
- Illuminate the audience regarding the structure of the data that your team received, and explain how data issues were resolved.
- Apply your team's approach to the data that you prepared for the analysis. Carefully elaborate on all undertaken modeling approaches, and clearly compare and contrast those.
- Fit the presentation within the reserved timeframe.
- Organize and deliver the presentation so that it is accessible to both quantitative and nontechnical audiences.
- Effectively address all the questions that the audience may have.

The written deliverable report for the management of Vespucci should:

- Effectively describe the problem that your client is facing and lay out your team's approach for solving it.
- Thoroughly explain the data cleaning undertaken by your team.
- Carefully apply the data-analytic approach designed by your team to the data that you received from the client and prepared for modeling. Include all the necessary technical sophistication, including but not limited to accurate residual diagnostics, model fitting summaries, and model validation.
- Clearly explain all the assumptions made in the course of your work.

In spite of the fact that there is no page limit for the written report, it has to satisfy certain requirements. The report should be written using Times New Roman 12-size font and 1-inch side margins. Moreover, the text should be double-spaced and the document should have page numbers. Clear captions and legends should accompany the figures and tables displayed in the document. Whenever applicable, the figures should have clearly labeled axes. The document should be spell-checked before submission and must be grammatically sound.

It should be stressed, that a number of subtleties regarding the data are intentionally excluded from the formulation of the business problem above and are instead supposed to be brought to light as a result of well-thought and relevant questions asked by you and your peers during the first status update meeting, at the latest. Note that the instructor, who will be serving as the "client" for this engagement, will not provide solutions, but may instead direct your team towards the right approach in case the team is considerably off track with its approach. During the final presentation, your team is expected to defend its approach by

Table 2. List of deliverables and tasks

Action Item	Description
Breakdown of responsibilities	Team notifies the instructor of the breakdown of responsibilities.
First status update	Team meets with the instructor to address the data-related inquiries. Questions regarding the definitions of data attributes, nature of missing values and outliers, as well as data dictionaries are especially pertinent at this meeting.
Second status update	Team meets with the instructor for an update on undertaken data cleaning efforts, as well as on the data-analytic approach. Relevant topics of discussion include but are not limited to resolution of missing values, outliers, duplicates, as well as the logic behind the data-analytic method.
Presentation	Team presents its work.
Deliverable report	Team submits the deliverable written report.
Peer evaluations	Each team member assesses his/her peers via an online survey.

clearly demonstrating how it works and by carefully addressing all the questions that the instructor/client may have. Moreover, your team is required to promptly attend to all the action items outlined in Table 2. You will be notified of the corresponding deadlines by the instructor at the engagement kick-off.

Finally, your grade for the engagement will be based on your presentation**,** the written deliverable report that your team will submit, as well as the results from peer evaluations that each team member will be required to submit at the end of the engagement.

You are given a unique opportunity to help Vespucci Advertising improve the pricing scheme of its digital billboard and thus generate the profit that it so desperately needs as a startup at the current, embryonic stage of its lifecycle. Good luck on your important mission!

6. DISCUSSION AND CONCLUSION

During the past several decades there has been an expressed skepticism in literature regarding the traditional, lecture-based instruction of statistics. The short-term retention of the lectured material, irrelevance of the format of the data presented during the traditional lectures, lack of teamwork and collaboration, coupled with the inability to integrate quantitative skills into decision making were all considered as drawbacks of passive learning. In contradistinction to the lecture-based instruction, many researchers have stressed the importance of experiential learning which addresses many of the previously mentioned gaps of lecture-only instruction. In particular, case studies, as a means of reaping the benefits of experiential learning, were advocated by many researchers. With regards to time series and business forecasting instruction, the importance of developing case studies has been stressed by academic and practitioner statisticians alike.

This article proposes an approach for teaching time series and forecasting with case studies that enable students to engage in a collaborative teamwork to solve nonstandard and ill-defined problems. As in the real world, no cookie-cutter approach is sufficient when tackling the business problems inherent in the proposed case studies, as those involve messy data and many blended, intertwined, and moving parts. In addition, the statistical consulting case studies provide a unique opportunity for students to apply the quantitative skills that they learn during the lecture and gain hands-on experience by working with information that resembles real data. As a result, and perhaps most importantly, the statistical consulting case studies impart the mindset that statistical consulting engagements are not simple data-analytic exercises that are solved by sole application of a method or two. The experience that students get from conducting a consulting engagement where the role of the consultant-statistician neither starts from a single tidy dataset nor finishes with the analysis of that data, is powerful. That the learning experience extends far beyond those boundaries into communication of questions to the client, business research, data cleaning, formulation of the solution approach, and business pitch of the findings, in each stage requiring the feeling of ownership and proactive participation is, in author's opinion, one of the most noteworthy benefits of statistical consulting case studies.

In the introductory time series course taught by the author the statistical consulting case studies were very well received by students. Several evidential reactions are in order. First, students were very excited about having to work with problems that concerned applications that occur in real life, and which, contrary to many textbook examples dealt with more realistic datasets. The data cleaning and preprocessing necessities did not seem to discourage the teams and those tasks were handled with the same enthusiasm and diligence as those pertaining to modeling. The learning that took place during the status update meetings through the dialog emerging between the teams and the author provided additional positive feedback. The inquiry-based fact-finding that took place during those 20–30 minutes dedicated to the meeting was very valuable for the student teams. This was reassuring, since by its sole nature, in an effective case study, the material part of the learning should take place through discussions, which in this case manifested themselves in the form of status update meetings. Finally, students were appreciative of the opportunity to apply the skills learned during the semester to tackle a problem which was non-standard and yet stimulating.

Despite this positive feedback, due to the novelty of the approach, no formal assessment of statistical consulting case studies yet exists. The hypothetical evaluation demonstrated in this article reveals that statistical consulting case studies invoke the learning objectives located in the higher echelons of Bloom's taxonomy. In addition, as was shown, by their very nature the consulting case studies fit nicely on the pillars of entrepreneurship education. The author is hopeful that a well-designed, controlled statistical experiment will illuminate further benefits of the statistical consulting case study approach in the near future.

In conclusion, it is worth noticing that due to all the features described in the article, in spite of having been implemented in a specific time series course, the statistical consulting case studies will fit well into broader undergraduate statistics curricula, and are consistent with the new guidelines for undergraduate statistics programs, issued by the American Statistical Association (ASA). Of note, the advantages of proposed case studies which are listed in Table 1 firmly hold even if the underlying data are not necessarily time series. Thus the statistical consulting case studies can in fact be equally well administered in, for instance an introductory categorical data analysis or data mining course. Further, because of their pronounced consulting flavor these case studies have immediate relevance for actual statistical consulting courses commonly offered at statistics departments. Moreover, with adaptations of scope to fit duration requirements (e.g., semester-long or year-long), statistical consulting case studies can be effectively extended to senior capstone projects, since the latter heavily rely on integrating knowledge acquired from different fields of study throughout the undergraduate education (Wagenaar 1993), as well as serving as a "rite of passage," preparing students for what realistically comes next in their professional lives (Durel 1993). Because of their interdisciplinary features, realistic data format, non-standard formulations, and emphasis on effective collaboration and communication skills, the overall format of statistical consulting case studies aligns with the characteristics of senior capstone projects.

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