Group Learning, Contextual Projects, Simulation Models and Student Presentations In Enticing Engineering Statistics Students

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Abstract

This paper discusses our teaching approach in graduate level Engineering Statistics. It is based on learning groups, contextual projects, discrete event simulation models and the use of modern technology, to entice student motivation. The use of group projects and presentations to generate, model, and analyze data in practical engineering applications, is discussed. Class topics division, course objectives, classroom strategies, testing, and grading schemes, software tools used and results obtained are also presented.

Introduction

Teaching statistics to engineering students has special characteristics. For, many engineers are not particularly drawn to the subject and believe it is outside of their main interest. But engineers work with real data. Hence, uncertainty is an unavoidable reality in their profession. Then, most engineering students take only one or two statistics courses in their curriculum, often theoretically oriented, with few practical examples and packed with material. None of this helps to raise student interest or their love for our statistics subject.

This is the situation we faced in ECS526, "Engineering Statistics", the Manufacturing Engineering and Engineering Management MS course at Syracuse University (SU) that provides the statistics methods for all other program courses. We wanted students to actively learn and retain the statistics concepts and procedures taught. But we also wanted students to gain other very useful abilities, of a more general character, in the process.

Hence, to entice engineering students to better learn and retain statistics, a series of new pedagogic methods and technological procedures were implemented. This paper overviews the specific problems we faced, the methods, we used to overcome them and the results obtained.

ECS526 Description, Needs and Wants

ECS (http://web.syr.edu/~jlromeu/Syllabus.html) is a survey course composed of three parts. The first five weeks cover basic probability (events, random variables, discrete, continuous and sampling distributions, variable transformations). The following five weeks cover inferential (confidence intervals, quality control, hypothesis tests and non parametrics). The final five weeks cover statistical modeling (regression, ANOVA). After each section (except the last, which is followed by a project) there is an in-class test (http://web.syr.edu/~jlromeu/ecschedul.html).

The class meets in the evenings, once per week, for three hours. Students are local practicing engineers and full time graduate students.

The course textbooks are Engineering Statistics (Walpole and Myers, 1998) and Statistical Analysis of Materials Data (Romeu and Grethlein, 1999). Over twenty tutorials that treat different course topics are available on the Web (http://web.syr.edu/~jlromeu/urlstats.html).

The innovations implemented respond to very specific needs and seek to obtain very specific objectives. For example (Romeu, 1998) some students have poor math background and study habits, or suffer from “math phobia”. Thence, multiple Web tutorials would provide additional explanations of course topics, via practical and numerical examples.

ECS526 curriculum is very ambitious. Hence, it has been divided into “classes of equivalences”. One “representative” is discussed in class and the remainder “class members” are assigned as Homework to student groups. For example, the “class” of confidence intervals includes CI for the mean, the proportion, the variance, difference of two means, of two proportions, etc. The Instructor develops the case of CI for the mean and assigns the others to student groups which present them in class and then share the material.

Finally, to overcome the passivity and lack of interest in some students, contextual projects suggested or generated by the learning groups themselves are utilized, generating the weekly student presentations of their solutions.

With this combined approach, several course goals and objectives were fulfilled. In addition to learning the whys and "how to's" of applied industrial statistics, several other very important goals were included. For, we also wanted to teach students to work in multidisciplinary teams and to redefine real problems in statistical terms, synthesizing, resolving and presenting them to others both, in technical and non technical ways.

Such additional objectives can be summarized in five points: to communicate fluidly (in writing and orally), to handle ambiguity, to work with others, to work alone and to acquire statistical knowledge. These equally important abilities will serve students well throughout their lives in many areas, way beyond statistics.

Pedagogical Methods Used

Five pillars support the learning process in our course: group learning, contextual projects, the use of statistics and simulation software, the use of email and the web to support instruction and student presentations of course material to their peers. We will discuss each one of them, next.

Group Work starts the first day of class. Student groups of four to six students are formed using the class list. In their first meeting students elect their group leaders and start functioning as a democratic unit. Groups decompose homework problems into parts and divide the work among group members. Once resolved, groups assemble and synthesize the results and prepare a written report and a PowerPoint presentation.

At the beginning of every class meeting, each group has ten minutes to present: statement, methods, result and conclusions. Then, students and the instructor ask questions, correct errors, signal omissions and improvements, and the material is expanded on and used to introduce new topics.

This part takes the first half of the three-hour, meeting. The second half is used to introduce new material and explain the following weekly group homework.

Assignments are sent via email to all students. In addition, solved problems, statistics tutorials, Minitab Execs, etc. are given in class or sent via email, or are available in the class Web Page.

Group work is the experience that students most enjoy in ECS526. They have told us, in their course evaluations, how they like to learn among themselves. As a note, only in a handful of occasions has a group disclosed dissatisfaction with any particular student work. The overwhelming majority of the times all students do contribute actively and constantly to the group effort.

Contextual Projects constitute a key element in raising student interest. For, it gives them topics they care about and captures their imagination. Students also know the problem background, so they only have to deal with one difficulty: statistics. They also see how statistics is applied in engineering, their main interest.

Students can define a project topic jointly with another course, where statistics may be used. Joint projects are always implemented with the consent of the other Instructors involved.

There are two main sources of contextual project topics. One is student background. Many of them are practicing engineers who face real-life problems in their daily work. Other times, the Instructor, who is also a statistical consultant in a reliability and quality assurance research center, brings problems for class discussion, sanitized to preserve the proprietary elements involved.

Final Projects constitute the student groups' "master piece". It provides students the thread for unifying all the concepts learned and as a vehicle on how to apply them in engineering.

At the beginning of the course, students receive a list of conditions that projects should meet. They should have enough data to implement one and two sample confidence intervals, hypothesis tests and, at least, univariate regression and one-way ANOVA. In addition, all model assumptions must be tested, or at least empirically assessed (e.g. normality, independence, and equality of residual variance, in regression).

Groups select, in the first five weeks of the course, a Final Project topic from discussions among its members. If a group is unable to select an acceptable topic in a reasonable time, the Instructor provides one. For example, a real industrial problem that has arisen in the Instructor's research and that is converted into a GPSS simulation program.

Final Projects are due at the end of the course and provide 20% of student final grade. Each group gives a PowerPoint presentation and a Word written report with problem resolution, conclusion and practical applications. Projects are evaluated on the quality of statistical methods used as well as the manner in which they were implemented. A Project example can be found in: http://web.syr.edu/~jlromeu/FinProEx.html.

Statistics and Simulation Software help students deal with calculations and overcome math phobia. Minitab statistics software was chosen because it is (1) available, (2) easy to learn and to use and (3) includes all the course procedures. Students are also taught how to use statistical routines in Microsoft Excel and several interactive examples of SAS are provided. This allows students to compare specialized statistics packages with general purpose software with statistics routines. They also compare the advantages of PC-based Minitab versus the interactive SAS that can be used via telnet from their dorms.

In addition, the software selected needs to be programmable, in order to write Execs with problems and examples that are then emailed. Students use these to practice and to better understand specific points that we want to make. For example, the Gamma (K, μ) distribution is also the sum of K independent Exponentials (μ). To verify this, students receive a Minitab Macro that implements empirically such a Gamma, and compares both results. Students also reproduce Web tutorials that explain how to do homework step by step.

The other software used is GPSS, a simulation package. Students are only required to run the student version programs, not to learn GPSS programming. Examples of simulation problems assigned to the student groups include analyzing two designs of a job shop. One has a fast lathe; the other has K slow ones. The problem is to substitute the 'old' lathes for a new and faster one. Management is interested in assessing whether the cost of buying the fast lathe will be amortized in reasonable time.

Different groups are given different parameters: lathe processing speeds, incoming job rates, number of lathes in the shop, etc. and different random seeds. Students then work with different performance measures: waiting time, time in system, utilization, number in queue, etc. This allows the students to cooperate with each others and to work together within groups.

The Internet, Email and Web Tutorials use is crucial. All the course information is available in our Web Page: syllabus, daily class topics and readings, homework, grading, etc. In addition, all course communications are done via email.

The Instructor keeps a data base with over fifty messages, with information about class topics and readings, explanatory materials, procedures, etc., that are sent, averaging five per week. Students send questions that are emailed back, posted in the Class Web Bulletin or sent out in a general email. Groups also email their weekly presentations to the Instructor, as well as to all the other groups. Since many of the students are full-time engineers and come only once a week to Campus, email communications is also their only way of maintaining contact with the group.

Course tutorials are accessible on the web. They were developed by the course Instructor as study materials for practicing engineers and are also available in booklet format. Topics include: goodness of fit tests, confidence intervals, tests of hypotheses, control charts, Exponential life tests for complete, and types I and II censored samples, series and parallel systems reliability, availability, Bayesian methods, etc.

Student group presentations are required every week. Problems are solved by groups using statistical software. They prepare a PowerPoint presentation discussing the problem statement, methods, results and conclusions and submit a written report. They input the corrections and send the files to all other groups in the class.

There are 10 weekly presentations, throughout the course. Group presentations yield 20% of each student final grade and group participation is assessed by their own group.

Course Evaluation is based on several elements. Two mid-terms, about 1/3 and 2/3 into the course, are given. Each consists of three parts: individual in-class, individual take-home and group work. Each mid-term is worth 30% of the student final grade. The first test covers probability, discrete and continuous distributions and transformations. The second test covers confidence intervals, hypothesis testing, quality control and basic non parametric procedures.

The individual in-class test is similar to any other traditional exam. Several practical and numerical exercises are given for students to resolve in a two-hour, open book test. This part yields 40% to 50% of the exam grade. Questions are meant to assess a student‘s basic knowledge. They may be asked to solve numerical problems using probability, Binomial, Poisson, Normal and Exponential distributions. In the second test, students may be asked to implement one and two sample tests and CI for means, variances or proportions, using the Normal, Student t , F and the Exponential distributions.

The individual take-home part is more involved, theoretical, and longer exercises are presented. Students are given a week to work on three or four complex problems where they have to apply the theory studied. In the first test students may be asked to derive the distribution of the minimum of a sample of “n” Exponentials or to transform a random variable. In the second, students may be asked to obtain the power of a hypothesis test.

The group part is an illustrative application of the theory via statistical software. In the first test, groups may reproduce the distribution of the Chi Square, from its theoretical definition. In the second test groups may be asked to run a GPSS simulation model of two job shops, collect the data and perform a paired t-test to compare performances. Students may have to determine sample sizes required to achieve a given power, for a pre-specified alternative.

Test weights are tuned so that students that work hard in the groups and learn the core material pass. Those that work well and have a good understanding, as well as the excellent students, can exhibit their talents in the individual and take home parts of the two mid-term tests.

Conclusions

In this paper, several pedagogical methods and modern technology, that help enhance and entice engineering statistics students’ learning and retention, have been presented and discussed. In addition, a real-life implementation of these teaching methods, (ECS526) was described.

The classroom use of technologies such as computers, the internet, email and statistical software, and modern pedagogical practices such as cooperative learning groups, contextual projects and student presentations were described in detail and illustrated via a case study.

Several performance measures can be offered to assess this work. First, we can now cover the extensive course material. Then, students learn it more and retain it longer. We know this because, after leaving the course, many local engineers write to let us know how they are applying it and to ask for more information about such methods.

In addition, students express in their course evaluations, personal contacts and in talking with other students and professors, how they enjoy course features such as student presentations and contextual projects. They admit that they work more than in other courses, but they still feel they learn more, while enjoying more their work.

Finally, this course is more fun to teach because it is much more involved and creative.

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