Catapulting Student Interest in Statistics: A little bit flipped, SCALE'd, and Real

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Abstract
One of the challenges of teaching statistics to any class is creating real data and connecting the methods taught to real-world examples. This is especially challenging in a graduate course with students in several different degree programs on campus—with a mixture of both Ph.D. candidates and masters students. The approach we describe is partially "flipped" with students preparing for each class with carefully selected reading and analysis assignments and the lecture part of the class becoming primarily discussion of the pre-work. Over half the class is then in a modified Student Centered Active Learning Environment – Undergraduate Programs (SCALE-UP) where custom designed six-student workstations enable in-class experimentation using special "nerd" kits. A key part of these kits is the catapult, a device wonderfully suited for regression experiments and experimental designs. Students work in six-person teams collecting data collection and analysis. The "real" part is done using carefully selected team projects with manufacturing companies and hospitals.

Key Words: Student Centered Active Learning, Lean Six Sigma, Data Analysis

1. Introduction

"Quality is no longer an issue." This statement has appeared in several business journals in the past few years. The authors are trying to make the point that we now know how to manage quality. What matters in building a competitive company is innovation, social marketing, supply-chain management, low-cost energy or whatever else the authors' are selling. In the past twelve months we have seen over 40 million automobiles recalled, nineteen deaths attributed to the failure of a 57 cent ignition switch; two airline crashes and one airline that just disappeared; a ferry capsizing with over 300 young people drowning; a gas tank car barrelling down a hill and exploding in the center of a small town; and numerous train derailments. We may know how to manage quality, but we are a long way from applying what we know in an effective fashion.

For the past twenty-five years many leading companies throughout the world have built their quality systems around the concepts pioneered by the Motorola Company and expanded and enhanced by General Electric and Allied Signal/Honeywell under the name Six Sigma Quality. Many other companies have developed quality systems based on the Toyota Production System often referred to as Lean Manufacturing. In the past few years these methods have often been combined as Lean Six Sigma.

For the past fourteen years in a partnership of the Colleges of Textiles and Engineering at North Carolina State University we have been teaching extension courses for our industry partners in Lean Six Sigma. These courses are similar to those taught in leading companies, by consulting firms, and by other universities. The Black Belt courses are taught in one-week blocks over the space of four months. The Green Belt courses are two-week courses spread over two months. All students arrived with a well-defined project. The students work on their projects during the classes and in the weeks between classes. In addition to the real data from the projects, real data is created in the classroom labs through the use of catapults and other exercises.

All students have laptop computers with state-of-the-art analysis software. In our courses we use both Minitab and JMP Pro 11. Within the software packages are many real data sets used in exercises. The courses are extremely interactive with students spending approximately half of each day conducting experiments, analyzing data and presenting results, and presenting progress on their individual projects.

Fourteen years ago we converted the existing course for third-year textile engineering students, "Process Improvement in Textile Engineering," to a Lean Six Sigma course. We soon added a graduate course in Lean Six Sigma that attracted both masters and Ph.D. students from the Colleges of Engineering and Textiles and also the Colleges of Natural Resources, Management, and Sciences. Our challenge was how to cover the critical material we felt necessary in Lean Six Sigma that was taught in our extension courses in over 144 hours of lectures, exercises and project work into a semester course of 48 hours. Of course, homework and other outside assignments adds significant hours over the semester, but we can easily fill the 48 hours of classroom time with lectures.

Both the College of Engineering and the College of Textiles have long histories of experiential learning with students spending much of their time in state-of-the-art laboratories and all participating in multi-disciplinary capstone projects. We were looking for a way to focus most of the classroom time on hands-on learning while covering almost all the material we provide in our extension Lean Six Sigma Black Belt courses. We wanted to cover most of the "hand tools" used in Lean Six Sigma, those methods that can be done by hand See Figure 1 below):

We also wanted to cover all of the statistical methods we call power tools, those that truly need to be done using sophisticated software (see Figure 2 below):

Another challenge is that our students come from many backgrounds and levels of experience. This past year, for example, in the graduate course we had 46 students from nine different degree programs: Fiber and Polymer Science, Textile Technology Management, Biomedical Engineering, Industrial Engineering, Textile Engineering, Integrated Manufacturing Systems Engineering, Textile Technology, Textile Chemistry and Textiles. Thirteen of these students were in Ph.D. programs, 31 in masters programs and two were undergraduates on fast-track BS/MS programs.

Our approach to this course was "a little bit flipped," a little bit "SCALEd," and a little bit real.

2. A Little Bit Flipped

Flipping courses is not new although it has been getting much attention in the past few years. Students cover much of the material prior to class through reading assignments, reviewing slides used in previous years' presentation, video presentations, and homework. Much of the introductory software work is done prior to class. Each class session starts with a discussion-based review of assignments. Lectures are used sparingly to cover some difficult parts of the material and to answer questions.

We had observed this approach in a number of other programs and used it partially in other courses we had taught. One outstanding example we reviewed was at the new medical school created jointly by Hofstra University and North Shore Long Island Jewish Health System, officially Hofstra North Shore-LIJ School of Medicine at Hofstra University. All material is covered in reading assignments prior to class. Classes are intensive interactive discussions with each student actively participating. Afternoons are spent in simulation labs applying what is learned.
We have found deciding what materials can be covered outside and prior to class quite challenging. We are still experimenting with what part of the course is best done through

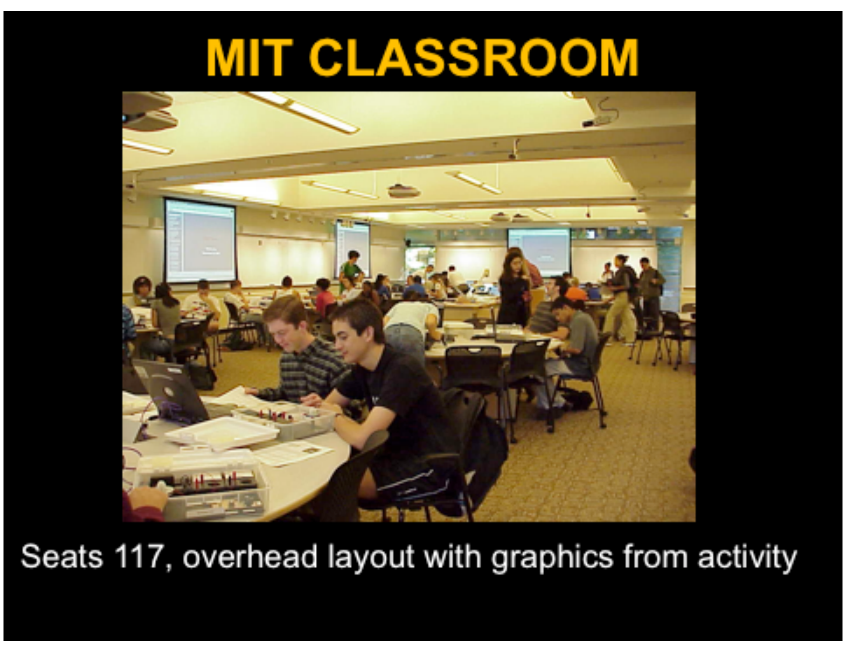
these prior assignments and what we need to cover carefully in class. Our intent is to use almost all the actual class time for experiments and hands-on data analysis, results presentations, and discussions of the findings in the analyses.

One tool that greatly assists in flipping the class is Moodle, a software web-based assignment tool called Wolfware at NC State University. Wolfware makes is easy to post assignments, make reading materials easy to download, permits url links, and allows students to view or download presentation slides or videos. Data sets can also be posted for analysis and students can upload their completed assignments, project presentations, and exams. Broadcast e-mails and announcements are also easy.

3. A Little Bit SCALE'd

To create the interactive environment we wanted in the classroom we used Bob Beichner's Student Centered Active Learning Environment for Undergraduate Programs, SCALE-UP. Professor Bob Beichner is a physics professor at NC State University who has pioneered a new way of teaching undergraduate physics. In Bob's words, "The primary goal of the Student Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) is to establish a highly collaborative, hands-on, computer-rich, interactive learning environment for large-enrollment courses."

The SCALE-UP approach has now been adopted and implemented in over 150 different universities first for similar large-enrollment physics classes but now in many universities for many different types of courses. Bob has published the results of his courses widely and has become a focal point for sharing the approach and learning from others as well. We talked with professors at Florida State, MIT and Virginia Tech using SCALE-UP for physics courses. In Professor Beichner's classroom eleven tables of nine students per table work interactively on physics experiments. Students at a table work first in three-person teams, then share their approach and results with the other students at the table, then one table is asked to share with the entire class. The MIT physics classroom is similar with space for 117 students with multiple overhead projectors, and well stocked "nerd kits" with all materials for each day's experiments (see Figure 3 below).



Florida State University uses a very similar layout for their physics classes. Unlike MIT, Florida State still offers physics classes in large lecture rooms also. They have found that some students find the collaborative, interactive SCALE-UP approach too intense and prefer the "sage on the stage approach" to the "coach on the sidelines." Figure 4.

Other universities have taken the SCALE-UP approach much further. Clemson University now offers SCALE-UP classes in calculus, general engineering, mechanical engineering, and civil engineering. The University of Minnesota has built a new building with 20 SCALE-UP classrooms. Within one year of opening, one-third of all Minnesota students had at least one class there.

We have designed a new classroom for our Lean Six Sigma courses patterned on Bob Beichner's design. Our class room has eight six-person tables where students work in teams of two or six. Each student has a personal laptop with JMP Pro 11 software. All laptops are electronically linked to the eight LCD screens for sharing their analyses and results with their team members or with the whole class. The instructor may also present on all eight screens at once to cover difficult material or give examples. Figure 5 below shows our new classroom

After a short discussion of the pre-assigned materials, we immediately go into experiments. These are the traditional experiments used in many Lean Six Sigma classes. For Measurement Systems Analysis we use micrometers, washers, and golf balls. For experimental design we used a catapult that has six adjustable factors. The catapult experiments cover five topics ranging from measurement error to human error to simple factorial experiments to fractional factorial experiments (Figure 6).

4. A Little Bit Real

The third part of our approach to making the course as hands-on as possible is real projects with local companies and hospitals. This past year we had six projects with three local hospitals and six projects with a textile manufacturing company. Five or six students work together on multi-disciplinary teams. The projects were championed at the locations by Lean Six Sigma leaders and executive leaders.

The projects included production scheduling, reducing redundant barcode scans, preadmission testing, improving operating room utilization, reducing time to complete an EKG, reducing the number of packaging SKUs, reducing hospital readmissions, and improving knitting machine efficiency. The students prepare both oral reports to share in the classroom and with the sponsoring organizations and final written reports. The lessons learned in these projects include how hard it is to get real, useful and accurate data and how hard it is to get even well-designed solutions implemented. The students often find that the analysis of the data and developing well-designed solutions is by far the easiest part of the problem.

5. Conclusions

Robert Beichner has extensively studied the impact of the SCALE-UP approach. His measures of impact have shown that:

1. Students ability to solve problems is improved,
2. Conceptual understanding is increased,
3. Attitudes are improved,
4. Failure rates are drastically reduced, especially for women and minorities,
5. “At risk” students do better in later engineering classes.

We have not done similar studies of impact. Ours is a graduate course with well-motivated and well-prepared students. We have no “control class” of similar students being taught in the usual lecture setting. Although in the past we used the lecture approach, we have been adding real data exercises, lab experiments, and real projects for many years. Ours has been an evolutionary approach to making the class more real and bringing into the classroom data from actual experiments and creating real data in the labs.

We do feel we have improved the academic teaching of Lean Six Sigma by reducing lecture time, increasing time spent on data analysis and experimentation, and building the real projects into the curriculum. Perhaps the best measure of the success of the class is the number of students who have reported that they got their internship or their first job because of having taken this class. Each year we hold a Lean Six Sigma Forum for our alumni and extension course graduates. We are always impressed with the presentations of our students and the significant problems they have solved.

Acknowledgements

The course we have described has been created over the past fourteen years and many professors have contributed to the content, the approach, the experiments, and the software. We first must acknowledge Professor Tim Clapp who created the Textile

Engineering Process Improvement course and was the leader in changing the course to Lean Six Sigma and worked tirelessly to add meaningful examples to the undergraduate and graduate courses. Professor Warren Jasper co-taught the graduate course for several years and brought more real life examples into the course. Professor Jeff Joines has for the past several years taught the undergraduate course and parts of the Master Black Belt modules. Professor Takeshi Nakajo as a visiting scholar added valuable content in error proofing based on his work in automotive assembly plants in Japan and with healthcare organizations and textile companies in the U.S.

Members of the Steve and Frosene Zeis Textile Extension Education for Economic Development Center have managed and taught many of our Lean Six Sigma Black Belt, Green Belt and Master Black Belt courses over the years often in close partnership with the Industrial Extension Service in the College of Engineering. Much of the quality of our course materials can be directly attributed to Dr. Lori Rothenberg, Gary Ward, Melissa Sharp, and Latoya Giles in our extension department and Kevin Grayson and Margaret O'Brien in the Industrial Extension Service.

Our friends at SAS Institute participated in many of our earliest courses using JMP adding new software tools and continuously improving the analysis capabilities of the software to support Lean Six Sigma projects. Almost every year they have taught special workshops at our Lean Six Sigma Forums introducing new analysis capabilities and sharing "tips and tricks."

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