QUALITY ENGINEERING: AN EXPERIENCE IN TEACHING STATISTICS FOR ENGINEERS

Adelmo Anselmo Martins, Elisa Henning and Marcelo Sávio Ramos
Santa Catarina State University, Joinville, Brazil
dep2aam@joinville.udesc.br, elisa.henning@udesc.br

In quality engineering, statistics focuses on manufacturing and process control, analyzing variation and quality in products, seeking to track process stability. In this sense, the main applications deal with statistical quality control in the analysis of the measurement system, experiment design and the Six Sigma methodology. All these methods use standardized procedures for data collection and analysis in order to identify, treat and eliminate sources of error in pursuit of continuous improvement in the quality of products and processes. Industrial engineers have contact with quality engineering at the end of the undergraduate program, and this article aims to present and analyze some experiments in the classroom developed in an engineering program. They are lab classes, applied exercises, real experiments, seminars and reviews of scientific articles. Since the program`s classes are at night, many students are already working in the industries, giving a different, more collaborative character to the class.

INTRODUCTION

Statistics is currently used in practically all scientific and technological fields. Its importance has been expanding and consolidating due to the growing need for resource management in several areas. In this sense, the playing field of statistics covers all sciences, including technology, such as engineering.

Statistical concepts and methods are not only useful, but also essential to understanding many everyday phenomena. They enable ways of perceiving several types of situations, allowing one to make correct judgments and decisions based on concrete results in the presence of uncertainties and variations (Konrath et al., 2013).

In engineering, statistics has wide application in the planning and process control of products and services. It is also important in the planning of new production strategies and sales forecasting. In this field, statistics focuses on process and manufacturing control, analyzing variation and quality in the products, trying to track process stability. Thus one of the main applications of statistics is in statistical quality control (SQC), which monitors variability using statistical control charts. In addition, there is the Six Sigma program, which applies standardized procedures for data collection and analysis to identify, treat and eliminate sources of error in the pursuit of improving quality and processes, with emphasis on reducing defects (Konrath et al., 2013).

As part of the undergraduate program, the teaching of statistics is present in virtually every curriculum, including courses in engineering. And, according to Louzada et al. (2010), no subject has interacted as much with other subjects as statistics. This reinforces the importance of a more critical eye in this direction. Furthermore, the Law of Guidelines and Bases of Brazilian Education (LDB 9394/96), which regulates the education system (public and private) in Brazil (from basic to higher education), shows the movement of curricula adding content for statistics at different educational levels in the country, making it very necessary to develop research and projects that provide meaningful, quality education in an area of importance such as statistics, including engineering.

In this article, we present pedagogical practices that are applied in a class (quality engineering) where production engineering students have greater contact with statistical tools applied to their area of knowledge. Initially we describe the class, its objectives and content, and then there is a discussion of the pedagogical practices. Finally, there are some conclusions and final remarks.

QUALITY ENGINEERING

Conceptually, quality engineering is formed by a cast of statistical tools, operations research and decision analysis, aiming to assist in the development and improvement of products

In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

and processes. The tools of quality engineering have been widely used in industrial businesses and service providers aimed at improving quality and productivity as well as the reduction of production costs. As a science, the main objective of quality engineering is to ensure that the quality of a product, process or service is at the stated or required level (Montgomery, 2004).

So it can be verified that quality engineering translates one of the principles that has always guided the area of quality: management based on facts and data, with the application of mathematical and statistical methods and techniques. So there is then a large set of tools and techniques related to quality engineering, both in the context of production and quality design, investing also in experimentation techniques (Deming, 1990; Juran & Gryna, 1992; ABEPRO 2009).

As an integral course of an undergraduate degree in production engineering, it can take on various characteristics. At the Santa Catarina State University (UDESC), Technological Sciences Center (CCT), it is a course in the 8th phase, with a semester workload of 72 hours, i.e. two weekly classes during a semester. The main goal of the course is to enable students to understand and use the techniques of quality engineering. As for specific objectives, at the end of the course, the student should be able to understand the importance of statistics for quality engineering, the fundamental principles of statistical process control (SPC), the use of process capability indices, acceptance sampling and the philosophy of the Six Sigma methodology. He should also be able to evaluate criteria and measures of quality of a product, make reproducibility and repeatability studies and have notions of the design of experiments within quality engineering.

PEDAGOGICAL PRACTICES

This course is, in accordance with the pedagogical design of the program, taught in the classroom as part of an engineering program that is offered at night. Thus, there are lectures in order to expose the concepts and theoretical background necessary at the beginning of each unit. The Moodle platform (Figure 1) is used as a support tool for classes. It is the main tool for the organization of the class, through the posting of lesson plans, materials for classes and office hours of the professor. All materials are also made available on the teacher's home page. This page is being maintained because not all students can access Moodle easily.

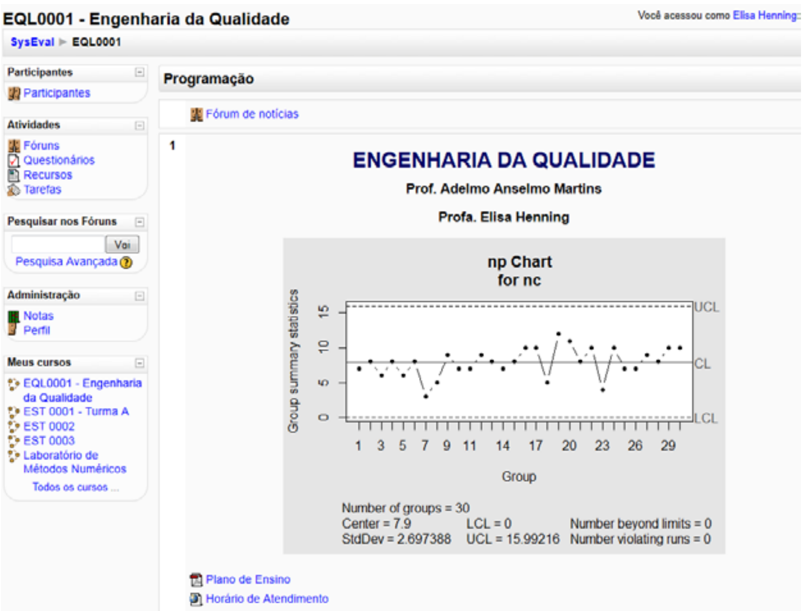

Figure 1. Class View in Moodle

In addition to the lectures, guided exercises in the classroom and also solving exercises in the computer lab are performed. It is noteworthy that the activity in the classroom is crucial because, as the course is nocturnal, students do not have much free time to study outside of class. Activities in the laboratory require application of control charts, process capability analysis, reproducibility and repeatability studies and introduction to the design of experiments. Starting on the second week of school, activities in the laboratory often have a weekly meeting. Until the first half of 2013, RStudio was used, while in the second half of 2013 we also started to use Statistica as an option in lab classes. The exercises solved in the laboratory were delivered in the form of individual or group reports through Moodle.

For the design of experiments, in the first half of 2013 we did the idea proposed by Box (1992). The basic idea was to construct a paper helicopter (Figure 2), and then analyze its flight time. With this in mind, students were asked what could influence the paper helicopter's flight time: paper type (related to weight), the shape of the wing or body and the presence of a paper clip at the base of the paper helicopter. Thus we performed a full factorial design, and, arranged into pairs, the students built the paper helicopters. Flight times of each paper helicopter were measured and then we proceeded to do an analysis of the data and results. At this point, it was easier to explain the possible interactions between factors. Moreover, some limitations of the experiment were discussed, which could influence the response variable. Finally, we commented how a fractional factorial experiment could be performed.

Regarding the Six Sigma methodology, the students had to do reviews of recent scientific papers published in conference proceedings and journals in the area of production engineering. The class was divided into teams, each of which received an article previously selected by the teachers. A seminar with an oral presentation and a discussion of the critical analysis of the articles was conducted. The review was posted on Moodle in a specific forum. Finally, the students had to review the work of other teams.

The students were graded on two written tests with a weight of 25% each, 25% for activities in the laboratory and classroom and 25% for the reviews of articles with group discussion on the Six Sigma methodology. We don't have criteria for the comparison of results yet, since it is the first time that the course is offered completely in this way, going beyond the lecture and grading only on tests and written assignments. But the results seem to be positive, because the pass rate was above 95%. And by analyzing the written tests, which covered the content learned in the laboratory, most students answered the questions relating to these matters correctly.

We know, however, that there is much to be done. One problem is that not all students still come to the class with the necessary basis. Some students have difficulties in basic statistics, not knowing how to interpret simple charts like histograms and boxplots, and difficulties in understanding the classic statistical tests. Thus, at the beginning of the semester, a review of basic statistics is still done.

Another difficulty is that as the course is nocturnal, students have little time for studying outside of class, as most of them work during the day. Thus, the class had to be designed to provide room for many activities. However, this gives another character to the class, making it more dynamic, with greater interaction between the class and the teachers. And there is yet another particular aspect. Some students already work using the studied methods in their day job, thus bringing experiences, questions and even suggestions that enrich the teaching learning process. We see that there are real problems with the assumption of normality, central to many of the methods studied.

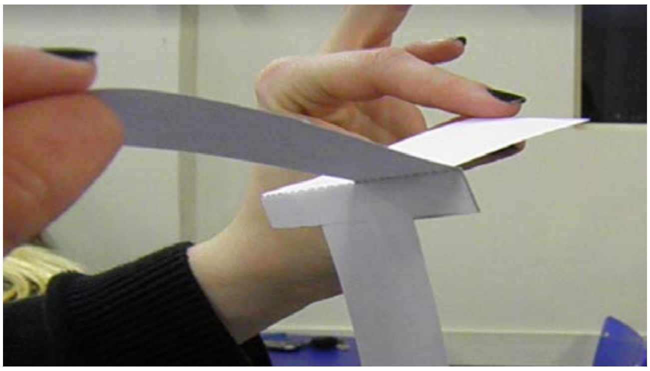

Figure 2. Paper helicopter constructed in one of the activities.

CONCLUSION

This article focused on some teaching practices with quality engineering classes. In addition to lectures, the practices cover laboratory exercises, experiments and critical reviews of scientific articles. Although the activities have had positive results, this project, as part of the teaching learning process, does not end here. As a continuation of our work, we are gradually introducing questionnaires and online exercises on the Moodle platform. The activity with paper helicopters can also be improved, based on the discussions about the limitations of the experiment. In addition, short videos about the applications of RStudio in quality engineering are being developed as complementary materials for the class.

Finally, we believe it is also essential to investigate studies of reproducibility and repeatability through experiments and other practices in teaching. This is a subject in which the theoretical framework can be further explored in order to clarify the interpretation of the results of these analyses.

Above all, we want the students, future engineers, to see statistics as a science present in their daily work, and also as an important field for continuing education.

REFERENCES

ABEPRO (2009). *Novas tendências em Gestão e Engenharia da Qualidade: Produtos e Serviços*. URL: www.abepro.org.br/arquivos/websites/27/SD05_Novas_Tendencias.doc.

Box, G. (1992). Teaching Engineers Experimental Design with a Paper Helicopter. *Quality Engineering*, *4*(3), 453 - 459.

Brasil, MEC (1996). Leis e Decretos. LDB - Lei de Diretrizes e Bases da Educação Nacional, Lei 9.394/96, de 4 de dezembro de 1996.

Deming, W. E. (1990). *Qualidade: a revolução da administração*. Rio de Janeiro: Marques-Saraiva.

Juran, J. M., & Gryna, F. M. (1992). *Controle da qualidade-handbook* (4. ed.). São Paulo: Makron Books & McGraw-Hill.

Konrath, A. C., Henning, E., Walter, O. M. F. C, Alves, C. C., & Wayne Samohyl, R. (2013). Applications in teaching Statistical Quality Control with different R interfaces. *2013 Proceedings of IEEE Global Engineering Education Conference (EDUCON)* (pp. 146 – 155), Berlin.

Louzada, F, Ara, A., Oliveira, C. Z., & Gonçalvez, C. V. (2010). Diagnóstico do ensino de estatística nas universidades públicas brasileiras: uma descrição de algumas das dimensões que compõem o perfil de seu corpo docente. *Revista Brasileira de Estatística*, *71*(234), 7 - 42.

Montgomery, D. C. (2004). *Introdução ao Controle Estatístico da Qualidade*. Rio de Janeiro. LTC.