AC 2008-704: AN ADVANCED QUALITY ENGINEERING COURSE FOR TECHNOLOGY

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An Advanced Quality Engineering Course for Technology Graduate Curriculum

Introduction

Due to fierce competition and globalized marketplace, companies are forced to operate on their lowest possible profit margin. In this context, it is argued that quality and variety are the critical order winning factors for any product types. However, introducing a new variety also introduces large variability in the product during manufacturing. This deteriorates the performance leading to significant product quality and reliability problems. A large number of recalls and warranty expenditures in various industries are indicators of poor product quality. To avoid such problems quality engineers and engineering technologist are required to apply various online and offline quality engineering and management tools both during design and manufacturing stage. Among the offline quality control techniques, the most popular techniques are design of experiments and Taguchi methods. Likewise, the statistical process control (SPC) technique is known as online quality control.

The SPC techniques can detect the 'in-control' and 'out-of –control' situation. If there are problems due to assignable causes (or out-of control situation), the control charts can be very handy tools in terms of detecting the causes. However, a process being 'in-control' does not necessarily guarantee a good part all the time. Therefore, in order to minimize the variability and also to optimize the product performance we need to redesign the product and process by building quality into them. To achieve that level of quality we need the techniques like experimental design and other off-line quality improvement techniques.

Competency gap

While there is no disagreement among academicians and practitioners on the importance of quality engineering to industry, it has not been given enough attention in most engineering curricula except in industrial engineering. Although the extent of topic may vary by discipline, per ABET Criteria 3(b) (c), which states that all should have the ability to design and conduct experiments and to analyze and interpret data skills[1]. Several educators and researchers in the past have studied the competencies gaps in the manufacturing engineering and manufacturing technology curricula. Lahidji and Albayyari[2] have conducted a survey on the competencies in the Manufacturing Engineering Technology programs. Their finding suggests that quality engineering is one of the thirteen major competency gaps found in the graduates of manufacturing engineers. In the same study, Lahidji[3] quotes that 69% of the respondents from industry rated quality as very important skills set that they would like to see in new manufacturing engineers. David Wells[4] suggests process engineering, product engineering, quality engineering, and production engineering as the essence of manufacturing engineering. While these papers primarily focused on undergraduate curriculum, the similar examples are found true in the graduate curriculum as well. Further, certainly need of quality engineering course in the graduate curriculum has been recognized and is a part of majority of the industrial and manufacturing engineering, systems engineering, and engineering management programs[5-8]. Unfortunately, industrial and manufacturing technology graduate programs are still lacking a major course in advance quality engineering such as design of experiments.

An introductory course in quality technology or statistical process control is typically found in any manufacturing technology program[2, 7]. The Indiana University Purdue University Fort Wayne's Master of Science in Technology has a core course on quality and productivity that covers basic concepts of quality management framework and statistical process control. As mentioned earlier, in order to deal with global competition, manufacturing companies are under tremendous pressure to increase product variety. Creating variety also creates challenges in terms of producing consistently high quality products due to introductions of new variability into the system. Therefore, it is important that our MS Tech curriculum (Industrial/Manufacturing Track) should also be augmented with a suitable course on quality engineering. However, in order to train the students in terms of long term solution to reduce the variability in product and process design, knowing just acceptance sampling and statistical process control is not enough. Figure 1 shows the various approaches of quality control and their scope in terms of reducing the variability in the product.

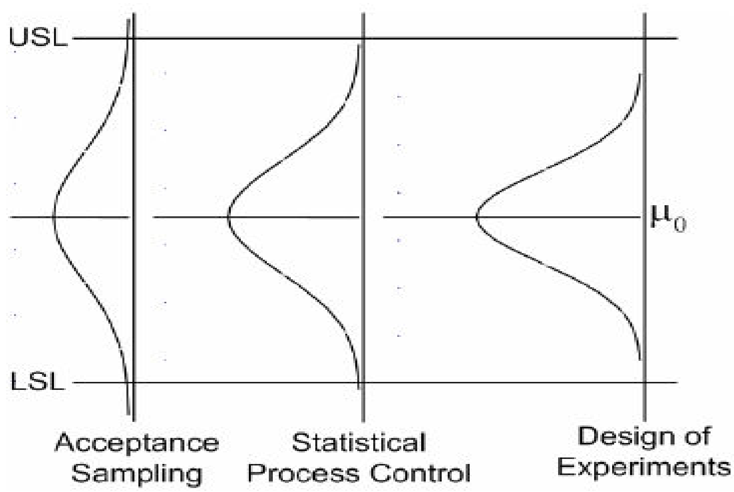

Figure 1: Potential levels of systematic variability reductions by using quality control techniques[9]

The above figure reveals that an advanced quality engineering techniques based on experimental design is the most effective approach for the maximum reduction of product or process outputs variability that is inherited in the process or product. As shown in the figure, the traditional acceptance sampling techniques and SPC techniques can just detect the quality situations but are limited in terms of reducing the variability by design. In order to optimize the design we have to use the techniques such as design of experiments and Taguchi Methods.

Justification for the course

Based on the literature review presented earlier, it is apparent that the Manufacturing Technology programs lack the quality engineering competency. Particularly, at the graduate level in Technology program, there is a strong need for an appropriate course on advanced quality engineering techniques. Industrial/Manufacturing Technology graduate programs are designed to prepare the students that can provide leadership in designing and manufacturing of products. This need was echoed during an informal survey of industrial advisory committee and current MS Technology students at the Indiana University Purdue University Fort Wayne (IPFW).

This paper presents a graduate level course for M.S. in Technology-Industrial & Manufacturing Technology Track on the application of advanced quality engineering methods such as design of experiments to improve the product and process. The course is tailored to meet the requirements of the technology graduate students. In other words, students will learn and get hands-on experience with quality engineering software which will be enhanced further by working on semester projects involving analysis of real world projects and published case studies. Further, the paper also outlines the teaching modules and modalities to enhance the learning outcomes of the subject.

Course objectives and outcomes

This course will expose students to modern quality philosophies and advanced quality engineering techniques. Topics include fractional factorial design, advanced statistical process control techniques, and correlation and regression analysis to understand the relationship amongst quality factors. The course will prepare students to take positions such as lead quality engineer or engineering technologist with a possible role in management. Students will have opportunity to use the quality engineering software. A great deal of learning will take place from the students' semester projects that will involve analysis of real world projects and published case studies.

Specifically, the course is structured to fulfill the following objectives:

- Learn an application of scientific thinking to study the real world industry problems.
- Understand, conduct and analyze comparative experiments.
- Understand and apply control charts for analysis of observational data.
- Design and conduct screening experiments, including graphical analysis.
- Design, conduct and analyze complete factorial experiments using numerical and graphical methods.
- Select fractional factorial experiment designs and conduct and analyze them.
- Apply (multiple) regression analysis to historical data sets and planned experiments.

Class activities and instructional methods

Engineering education has seen significant reforms over the years. One important change is in teaching method and curriculum development. Today's curriculum integrates a larger practice based component in the courses[12]. Domblesky et al.[10] further describe that the above change, in part, was triggered by industry criticism that engineering students are entering the workforce with lack of competency, which has necessitated remedial training on the part of the employer. In order to narrow down this gap, this course has a greater emphasis on the applied projects. Further, the class activities, homework problems, exams, and instructional methods are tailored for Technology students. Gadalla[7] presents the suggested educational practice in the Engineering, Engineering Technology and Industrial Technology programs curricula. The author highlights that the Industrial Technology program focuses more on the hands-on tools and group activities [see Figure 2]. This course is developed along the same guidelines.

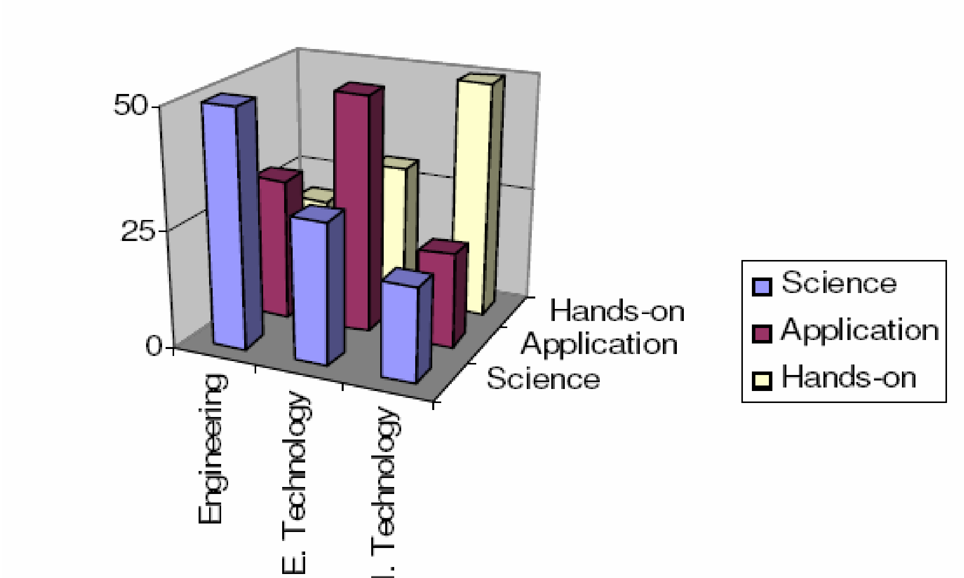

Figure 2: Suggested educational information model for engineering and technology programs [7]

Besides the traditional homework assignments and exams, the students are expected to complete and present their project work to the class. The project can be a research paper or an analysis of a real world case study. At IPFW, the class format consists of 150 minutes lectures each week, fifteen weeks total plus one final exam week. However, the class activities may vary from one university system to another and also from one instructor to another as some of the universities offer four credit hours courses.

Similarly, the grading policy may vary from one instructor to another. A general guideline followed in the proposed course is as follows:

Case study and homework: 20%
Article presentation: 15%
Group Project: 30% (oral and written)
Exams: 35%

Case Study and Homework
Homework will be assigned upon completion of each major topic. The homework can be designed of two types. First, regular type homework problems that can be solved using the methods and tools learned in the relevant session. The second type of homework problems are more of open ended and 'boundary-spanning' in which student minds are challenged to think critically in order to come up with a practical solution- a close representation of real world problems. Depending upon the class size, students can be assigned to small case studies problem given in the textbooks to reinforce their learning.

Article Presentation
A class can be divided into multiple groups with three to four students in each. Each team reviews one article for the benefit of the class. The team initially identifies a set of two-three articles that they would like to review. These articles should be application oriented, focusing on

one or more of the techniques being covered in this course. They submit copies of these articles to the instructor for review by the fourth week of the semester indicating their preference. The instructor would then inform of the assignment of articles in a week time. All the teams would then make a presentation on their assigned article in class towards the end of the semester. These presentations would be peer reviewed based on a set of guidelines. Articles could be found in the relevant management Journals and Magazines that a university subscribes to. Students select papers based on topic/problem that interests the team and covers some of the techniques discussed in class. Interaction with instructor and with other classmates/teams in this regard is encouraged.

Group Project
Each group (of 3-4 students depending upon the class size) identifies a project problem that they would like to work on. This work is meant to be representative of an actual design quality improvement project for which students are likely to be responsible in the real world. While there are no specific requirements for project scope or level of complexity, the project should be doable in terms of scope yet comprehensive enough to allow students to demonstrate the understanding of key experimental design concepts discussed in the class. A detailed guideline on how to prepare the project report and presentation slides is provided to the students early on in the semester.

Exams
In this course, two exams are suggested: one mid semester and one at the end of the semester. To reinforce the student's learning, few intermediate quizzes can be conducted after the end of each module.

Tentative course outline
The scope and depth of the materials covered in the course may vary depending upon the credit hours, nature of the student population, and the individual instructor. This paper suggests following three modules[11-13] for a typical three credit hours quality engineering course in M.S. in Technology program under Manufacturing Track.

<u>Module-1: Basic Statistics and Statistical Process Control</u>
Basic statistical concepts
- Sampling and sampling distribution
- Hypothesis testing
- Sample size
- Paired comparison problems

Statistical process control
- Review of control charts
- Attribute control charts
- EWMA and Shewhart process control charts
- Review of process capability studies

<u>Module-2: Design of Experiments</u>
Design of Experiments- a review of classical approach
- Experiments with single factor

Analysis of variance
Analysis of the fixed effects model
Practical interpretation of results
Computer output

Completely randomized and randomized block designs

2^K factorial design
Two-level fractional factorial design
Three level full and fractional factorial designs
Statistical analysis of fixed effects model

<u>Module-3: Taguchi Methods</u>
Quality Loss Function
Introduction
Quality loss function for various quality characteristics
Specification tolerance
Tolerance design

Signal to Noise Ratio
Introduction
S/N ratio for continuous variables
S/N ratio for classified variables

Introduction to robust engineering
System design
Parameter design
Tolerance design
Taguchi's approach to design of experiment

Conclusions

While there is a growing need for quality engineering professionals in the current global manufacturing world, research has shown that the manufacturing engineering technology and industrial technology graduates still lack a core competency in quality engineering. This has drawn a strong interest among educators and practitioners to develop a set of appropriate courses in quality engineering and management. Although, it is widely being offered in Industrial and Manufacturing Engineering programs, many Manufacturing Technology programs do not offer advance quality engineering course. This paper has presented a graduate level quality engineering course for Master of Science in Technology program with Manufacturing Track. The course content is designed to suit the technology students and focused on applications of hands-on techniques of advanced quality engineering. The course curriculum included review of publish papers and case studies and working on group projects. A tentative course outline comprising of experimental designs techniques has been proposed to meet the requirements of the current industry needs to improve the quality and reduce the variability of the product and process. Upon successful completion of this course, a student is expected to perform and analyze factorial design, advanced statistical process control techniques, and correlation and regression analysis to understand the relationship amongst quality factors. The course will prepare students to take positions such as lead quality engineer or engineering technologist with a possible role in management. Furthermore, it will also help students prepare the professional development exams such as *Certified Quality Engineer* and *Six-Sigma Green Belt* certification examinations.

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