Teaching methodology for Design for Six Sigma and Quality techniques – an approach that combines theory and practice

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ABSTRACT
Quality techniques and Design for Six Sigma methodology are complex areas that need to be understood through correlation of theoretical and practical teaching. Universities started to apply different approaches for achieving better results, on building greater knowledge and skills for their students.

The paper presents a methodology of teaching quality techniques and DFSS methodology, an approach that is focused on understanding the concepts through technical examples from industry and applying the knowledge within a project. A model is proposed for teaching Design for Six Sigma methodology through a workshop done in the classroom. The students are split into groups and will practically work through the main elements of DFSS methodology, for improving the quality of a chosen product by re-designing it.

The objective of research is to analyze the performance of this methodology and to identify the strong points. The measurement is done through feedbacks received from students, that is presented at the end of the paper.

The methodologies used during research consist of bibliographic research, observational study on classroom, questionnaire and interview technique.

Keywords: Quality, Design for Six Sigma, teaching methodology, industry

INTRODUCTION
DFSS methodology is applied in different industries, like healthcare, finance, marketing, automotive, process industries; creating a need for qualified people in this field. More than that, studies show that the Design for Six Sigma methodology helps in engineering education, forming a quality-focused way of thinking and anticipating potential limitations in product design, as well as preparation of students for the workforce (Babajide, 2015). Considering the learning process, it can be observed an increase in the need of applying practical exercises during training of academic concepts (Kanigolla, 2013), therefore project-based approach is considered to provide improvements in the development of students.

The engineering academic project proposed in this paper is designed for students, to experience real-world tasks and problems in an educational environment, with a final purpose in achieving confidence and be prepared for a real job work.

The researched domain is important because Six Sigma quality techniques and methodology are increasingly required on the market, especially in the industry; universities need to use new approaches to prepare students for the best.
The primary objective of the research is to measure the performance of the project-based approach, measured by checking feedback from students and analyzing the students’ work output.

The paper is constructed on the following structure:
1. Briefly review the research on academic approaches for the learning of Six Sigma methodologies; as well as research on Design for Six Sigma methodology. (Section 2).
2. A model is proposed for teaching Design for Six Sigma methodology, through a project-based seminar, during a semester. At the end of chapter, it’s explained the whole quality framework that was implemented in University; course plus seminar. (section 3)
3. The proposed teaching model is evaluated through students’ feedback and by analysis of work output (the degree of applicability in real-world, industry, the level of innovation). (section 4)
4. The last section of paper highlights the paper’s conclusions and suggests further research objectives.

TEACHING QUALITY TECHNIQUES

Six Sigma and Design for Six Sigma methodologies are widely used inside organizations to improve their business and their products. The approaches proved to be effective and productive, the level of effectiveness being raised by the team trainings and experience.

In the early ages, the training was created and deployed direct by organizations, after the team was employed. Now, universities started to create a framework for training the students, building the necessary knowledge and creating a correct mind set.

A model for teaching in higher education the Six Sigma methodology (figure 1) has been proposed in literature; the model is designed to be similar with the deployment from corporates, being composed of ten steps that includes some variations that are appropriate for the education sector.

The model author states that it’s important to equip the students with the right knowledge about quality tools and techniques for process improvements, as the student teams will lead the project assignments as part of the framework.

The learning process was designed as a team project for promoting mutual learning between members, to promote thinking and innovation through ideas from diverse minds, build a responsibility and experience the division of work (Sunder, 2014).

![Figure 1. Six Sigma model for higher education (Sunder, 2014)](image-url)
The current research is proposing and presenting a model of teaching Design for Six Sigma, a subset of Six Sigma that is focusing on preventing problems and integrating customer’s needs and requirements in the early stages of product design.

Design for Six Sigma is a structured method for developing new products, aligned with the needs of customers, which is involved during the early stages of product development. Various techniques are used within the methodology like anticipation of potential problems/needs, identification of current problem/needs, predictive engineering and management of actions used to improve product design (Nicolaescu, 2014).

For deployment of Design for Six Sigma methodology different process approaches have been proposed:

- DMADV; that is driven by following phases: Define – Measure – Analyse – Design – Validate (Deshpande, 2016) (Cronemyr, 2007)
- CDDOV; Concept - Define, Design, Optimization and verification phases.
- IDOV; Concept-Design-Optimize-Verify
- IDDOV; Identify-Define-Develop-Optimize-Verify (Coney E., Furterer S., 2012);
- RADIOV; Requirements – Architecture – Design – Integration - Optimization – Verification (Maass, E., McNair, P., 2010); designed for HW and SW products.

Even if the processes use a different flow, most of the steps and quality instruments/methods are the same. The basic activities that are performed in approaches of Design for Six Sigma are: capture of customer needs and requirements, analyze and prioritization of requirements, transformation of customer requirements into engineering requirements, development of design, structure of requirements on disciplines, sub-systems and components, verification of performance, realization of actions for the low performance characteristics, creation of a control plan and knowledge documentation (Nicolaescu, 2016). Even without a strict implementation, the usage of Design for Six Sigma will contribute to the alignment of activities and view of product development process (Ericsson, 2016).

**MODEL OF TEACHING DESIGN FOR SIX SIGMA METHODOLOGY**

The model proposes learning of Design for Six Sigma methodology by experimenting the development of a project, following the DMADV methodology. The following requirements were considered during its design:

- The deployment shall be similar with the approaches from organizations; some particularities are changed to better suit the educational environment;
- Knowledge on main instruments and techniques shall be shared through practical methods;
- The work activities will be applied to real-world products or processes;
- The work will be done in groups.

The focus is on the flow and understanding the quality instruments and their purpose (not on the actual process phases, Define - Measure - Analyze - Design - Validate); same approach as used in industry. For a better understanding of project, the activities were divided in 7 phases. Each of them include the theoretical understanding and practical exercise of quality instruments.

**Phase 1: Overview on Design for Six methodology in gained and product is identified/established.**

To establish the need and importance of this quality approach the teaching will start with:

- Theoretical aspects on quality, with examples on non-quality costs.
- The phases of product development, from research, design and development until production and support;
- Six Sigma and Design for Six Sigma methodologies;
- DMADV process of DFSS methodology.

First, needs to be identified a market segment and a specific need, afterwards will be continued with research on products that each group of students will apply the methodology (figure 2) for re-designing it, using quality techniques and innovation. The following instruments will be used: journals, internet, library or brainstorming technique.
Market segment and a specific need is identified

Identify customer requirements

Brainstorming / Survey / Interview

Requirement hierarchy

Kano, KJ Diagram AHP / Paired comparison

Importance of requirements

QFD block - Customer importance

Selected Product variant

Predefine product variants & selection

Brainstorming

Pugh method

Work experience

Varianta produs

Identification of product technical characteristics

VOCT1, VOCT2 Flow diagram

Correlation of requirements - technical characteristics (CTQs) and deployment of quality function up to the component level

Quality Function Deployment (House of Quality)

Figure 2. Design for Six Sigma project-based teaching methodology

The teacher will present examples of products, which can be easily obtained by adding a new function to an existing product, changing the original purpose of product etc. Each student will select a product that is used by them or they think could be re-designed through innovation.

After the research on the product / process is finished, the practical work will start with the planning component, the objectives will be defined and the main activities will be scheduled.

Phase 2: Identification of customer needs and requirements.

For identifying the customer needs and requirements for the products, brainstorming and interview are applied inside classroom. The interview is conducted bilateral between the colleagues of project and the needs and requirements are extracted from it. The questionnaire will be created and applied by each student, on the workplace or to the target market.

Phase 3: The hierarchy of requirements is achieved.

For the prioritization of needs and requirement the following instruments will be used:

- KJ Diagram: the requirements and needs will be grouped; the analysis allows the team to quickly reach consensus on priorities in relation to subjective and qualitative data.
- Kano mode: the requirements will be split in three groups, standard, performance and excitement.
- Analytic Hierarchy Process (AHP) will be used to calculate the importance of requirements.

The output of this section are the needs that the product can achieve for the customer and the importance of each requirement. Starting from this, product variants will be predefined and a most suitable one will be selected using the Pugh method.
Phase 4: Select a product design.
The Pugh method transforms a subjective decision into an objective one; it is also called decision matrix method.
Realization steps:
1. The selection criteria are chosen;
2. An importance for each criterion is established;
3. Product concepts are identified;
4. A score is given for each criterion for each product variant.
Qualica QFD software tool was used for building the Pugh Matrix (more detail about quality software tool at the end of chapter).

Phase 5: Identify technical characteristics of product
To support the creation of Quality House, the Voice of Customer instrument is used. Helps to systematically analyze customer requirements by asking a number of common questions:
- Who is the customer?
- What does he or she really mean?
- When was the requirement found?
- Where was the requirement found?
- Why does the customer want this?
- How can it be done?

Phase 6: Quality function deployment
The quality instrument is used to:
- Analyze and document the voice of the customer.
- Can be described as a translator of the customer voice in voice of engineer.
- The QFD method is applied based on a graphical model called House of Quality (figure 4).
- In most cases, the needs and requirements resulting from the "voice of the client" are normally expressed through daily language.
- To be able to design a product it is necessary that the requirements are made of precise technical terms, these requirements expressed in business language or engineering are called "quality characteristics" or CTQ.

Phase 7: Product schematic design
based on the importance of features / functions / components
The following outputs / instruments could be used: sequence diagrams, state machines, flow diagrams, object model diagrams, Visio diagrams, pictures, CAD tools.
Qualica QFD is a toolkit designed to help organize QFD projects and analyze results; the software can be used for other methods as Target Costing, Value and Risk Analysis and Design for Six Sigma (Qualica User Guide, 2017). The following instruments are available: Pugh new concept selection, Effect matrix, Voice of the Customer, AHP, and Quality Function Deployment.

In this section is presented the entire framework used to teach quality techniques (Figure 5). The course teaches the theoretical aspect of quality tools as well as the Six Sigma methodology. The seminar is structured as a project and covers practical learning, with examples from industry (explained at the beginning of the chapter).

There is a strong connection between the course and project based on the seminar. The first one has the purpose to assimilate the theoretical part and understand the need and importance of quality techniques; while the seminar has the main purpose of teaching with hands-on, experiencing a work environment that is very close to the one from industry.

**APPROACH PERFORMANCE MEASUREMENT**

The research was performed on a master program of Quality Management from Lucian Blaga University of Sibiu. 33 students participated in this project based seminar, being divided into teams between two and three students.

The following KPIs were used for the evaluation:
- The objectives of the seminar / project are clearly presented;
- Easy-to-understand examples are used (case studies, simulations, applications, etc.);
- Modern teaching tools (video projector, software applications, smart-board, audio-video, e-learning, etc.);
- The seminar support is well structured and useful;
- The content of seminar support is up to date;
- The model of teaching assures that the students understood the transmitted message;
- The problems raised by the students are clarified;
- The requirements and evaluation criteria are clearly formulated;
- Objectively appreciated the level of student training;
- Conflicts of opinions are accepted.
Figure 6. Student feedback for Professor & Program

Note: A Likert type 5-point scale was used; 1 – Strongly disagree, 2 – Disagree, 3 – Undecided, 4 - Agree, 5 – Strongly agree

A brief explanation of projects is related in table below. The projects analyzed and split between innovative (a new function was integrated into an existing product or two products were combined), and industry applied projects (the homework was done on the organization’s site, where the student made practical work).

Table 1. Analyze of projects (innovative and industry applied)

| Id | Project name                   | Description                                                                 | Type (Innovative / applied in industry)                          |
|----|--------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------|
| 1  | Toy with special functions     | Toys that record and play music with parents’ voice.                       | Innovative product (product design – integration of new function) |
| 2  | Record Pen                    | Pen with a feature that transfer written information in digital storage.    | Innovative product (product design – integration of new function) |
| 3  | Air freshener with special functions | Air freshener with smoke detection sensor and photovoltaic cell power supply | Innovative product (product design – combination of two products) |
| 4  | MaxClear Dent                 | Toothbrush with included toothpaste, designed for hotel chains.             | Innovative product (product design – combination of two products) |
| 5  | Intelligent carpet            | Carpet with function of wake-up alarm                                      | Innovative product (product design – integration of new functions) |
CONCLUSIONS

To prepare the students for real-work tasks and problems a model is proposed for teaching quality techniques and Design for Six Sigma methodology through a correlation of theoretical and practical teaching.

The model is similar with the approaches from industry and is applied to real-world products, in this way the students are experiencing similar activities and will achieve confidence for a future job.

The evaluation of the model is done through the student feedback, being selected relevant KPIs for the quality and efficiency of teaching. The results are finding the model suitable for training the students in a modern environment, though easy to understand examples.

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