TOWARDS A SIMPLE APPROACH BASED ON PROCESS IMPROVEMENT TO MEASURE QUALITY INDICATORS IN HIGHER EDUCATION INSTITUTIONS

Edited by
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On the theme: "The Application of Regional and International Indicators of Academic Quality and Accreditation in Universities in the Islamic World- Towards Excellence As a Means Not Merely On Outcome"
ABSTRACT

The paper is dedicated to present a simple yet efficient approach to measure quality indicators in higher education institutions. The approach is based on the fundamental concepts of total quality management; these are: Customer (Student/Teacher) Focus, Continuous Process Improvement, Management by facts and data and People involvement. The paper starts with a review of basic concepts on process improvement and ends up with a practical approach to apply these total quality concepts within the sphere of higher education environment in the Arab world. A special focus will be made on the use of the basic quality tools known as “the seven magnificent” by educators to measure quality indicators and to improve the quality of the learning process in courses at higher education institutions. A case study of an introductory engineering course delivered to first year engineering students at the University of Hail will be presented and discussed using these tools and techniques. The use of this approach by faculty members revealed great areas of improvement in:

- The management of the course and the delivery of its contents.
- The management of the learning and teaching process;
- The management of the educational process including its three major components (Teaching, research and community services).

KEYWORDS: Higher education; Continuous Process Improvement; Quality Tools; TQM in education, Quality Indicators.
INTRODUCTION

In the era of competitive markets and globalization, the quality concept has emerged as a strategic issue at all levels and in all industries including the education business. Quality in engineering education is a subject of actual concern for educators, educational leaders and to industrial business sectors. International quality standards and excellence models such the ISO 9000 standards, the EFQM model and the King Abdulazziz quality Award model require organizations' quality systems to be built on processes, rather than requirements, departments or functions. Consequently, process management has become more relevant, and proper process identification and management are becoming critical challenges for quality professionals, educators and higher education leaders. Many organizations use total quality management (TQM) tools to identify, analyze and assess qualitative and quantitative data that are relevant to their processes. One of the simplest and most effective tools used by engineers in manufacturing processes for problem solving and quality improvement, are the basic quality tools known as the magnificent seven. The Japanese quality guru, Kaoru Ishikawa who is the inventor of the seven basic quality tools stated that 95% of quality related problems in any organization can be resolved using these tools; This important statement has been proven in the field by different organizations and researchers including in higher education institutions (Aichouni (2007, 2010), Mukhopadhyay and Nataraja, (2004), Dias and Saraiva (2004), Gunther, and Hawkins, (1999)). It is worth mentioning that these simple tools which are listed under the Body of Knowledge (BoK) in the American Society of Quality Certification program, are usually taught to engineering and technical students.

In pursuit of quality, educators are continuously engaged in a process of finding opportunities for improvement of the learning process, the quality of learning experiences and the way education is delivered. In the present paper we will go back to review basic concepts on process improvement and quality management and to examine the possibility of applying these concepts within the sphere of engineering education. A special focus will be made on the use of the basic quality tools by educators to solve problems and to improve the quality of the learning process in engineering courses at higher education institutions. A case study of an introductory engineering course delivered to first year engineering students at the University of Hail (total number of students enrolled to the course during the first semester 2009/2010 was 536) will be presented and discussed using these tools and techniques.
2. BASIC CONCEPTS OF CONTINUOUS PROCESS IMPROVEMENT

2.1. Why do we need to improve processes and quality?

Edwards Deming, in his book "out of the crisis" published in 1986, answers this fundamental question with his famous Deming Chain Quality Reaction shown in figure 1. The benefits from quality and process improvements to any organization including the higher educational institutions are:

- Improve Quality (Faculty, Students, courses).
- Costs decrease (Fewer mistakes, better use of faculty time and knowledge sources)
- Productivity Improves (Students projects, Advanced level in teaching courses)
- Capture the market (Meet most of stakeholders expectations (government, society, industries, students)
- Stay in Business (Get international accreditation)
- Provide jobs and more jobs (Reputation, higher retention rate for both faculty and students).

![Figure 1: Deming Chain Quality Reaction as for Educational Institutions](image)

2.2. How to ensure Continuous process improvement? The PDCA Cycle

The most common process of continuous improvement is the PDCA Cycle, which was first developed by Walter Shewhart in the 1920s, and promoted effectively from the 1950s by quality guru Dr Edwards Deming, as a strategy to achieve breakthrough improvements in processes. The four steps in the cycle which is also known as the Deming Wheel, are as shown on figure 2: PLAN what is to be done and how it should be done; next, carry out the plan (DO it). Third, CHECK and analyse the results obtained and finally, ACT on the results by identifying what worked as planned and what did not, make a prioritization of the improvement opportunities and then carry on the improvements in the system.
Figure 2: The Deming PDCA Cycle of Continuous Process Improvement

(Steyn, 2000)

Seven phases have been identified by quality scholars to implement the PDCA cycle in the improvement process of an organization (Aichouni (2007) and Nankana (2005)):

- **Phase 1** - Identify the Opportunity for improvement
- **Phase 2** - Analyze the Current Process
- **Phase 3** - Develop Optimal Solutions
- **Phase 4** - Implement Changes
- **Phase 5** - Study the Results
- **Phase 6** - Standardize the Solution
- **Phase 7** - Plan for the Future

### 2.3. The Seven Basic Quality Tools

Once the quality improvement process is understood, the addition of quality tools can make the process proceed in a systematic manner. Many quality tools are available for quality professionals for this purpose. Organizations use total quality management (TQM) tools to identify, analyze and assess qualitative and quantitative data that are relevant to their processes. These tools can be generally classified into three major categories, namely: (a) the basic seven quality tools, (b) the seven new tools for management and planning and (c) other tools. The seven basic quality tools are simple tools that can be used by any professional to ease the quality improvement process; These are: flowcharts, check sheets, Pareto diagram, cause and effect diagram, histogram, scatter diagram, and control charts.

These tools were originally developed by Kaoru Ishikawa, one of the pioneers of the Japanese quality movement. Ishikawa's original list did not include flowcharts; instead, it had graphs as one of the tools. These seven
basic tools have been considered a part of Statistical Process Control (SPC), a quality management system that uses a set of tools to analyze, control, manage, and improve process quality. But not all seven tools are quantitative, let alone statistical. The flowchart is simply a visual description of a process. A cause-and-effect diagram is a brainstorming-based problem-solving procedure. Check sheets and Pareto diagrams are simply commonsense tools. Histograms, scatter diagrams, and control charts are the only statistical tools in the list. Table 1 shows the seven tools and their applications within the PDCA cycle for process improvement.

Quality pioneer Ishikawa stated that 95% of quality-related problems in any organisation can be solved with these basic tools. This statement has been proven by many organisations and researchers as it will be shown later. The key to their success in problem-solving and process improvement initiatives are their simplicity, ease of use and their graphical nature. The tools were originally meant to make process analysis less complicated for the average factory worker in Japan, but now they constitute standard analytical tools to analyze quality problems and develop and identify optimum solutions and standardise them. They can easily be taught to any member of the organisation. These tools have been widely used in manufacturing and services embracing process-improvement initiatives such as Total Quality Management (TQM) and Six Sigma.

These tools have been extensively described in textbook (Brassard and Ritter (1994), Grant and Leavenworth (1999), Juran (2000), Nancy (2004), Nankan (2005) and more recently by Aichouni (2007, 2010). A brief description of these tools is shown in the following section (figure 3):

- **Flowchart**: is a graphical display of the process steps in proper sequence. It shows all process steps under analysis by the quality improvement team, identify critical process points for control, suggest areas for further improvement, and help explain what is really done?

- **Check sheet**: A structured, prepared form for collecting and analyzing data; a generic tool that can be used to identify how often a problem occurs.

- **Pareto chart**: Shows on a bar graph which factors are more significant. What are the major problems in the process?

- **Histogram**: The most commonly used graph for showing frequency distributions, or how often each different value in a set of data occurs. What the variations look like?
• **Cause-and-effect diagram** (also called Ishikawa or fishbone chart): Identifies many possible causes for an effect or problem and sorts ideas into useful categories.

• **Scatter diagram**: Graphs pairs of numerical data, one variable on each axis, to look for a relationship between process variables and factors.

• **Control charts**: Graphs used to study how the process changes over time. It helps to identify the variations to be controlled and how this can be achieved?

### Table 1: The 7 Basic Quality Tools and Their Use in the PDCA Improvement Cycle

<table>
<thead>
<tr>
<th>Tools and Techniques</th>
<th>Identify Opportunity</th>
<th>Analyze Process</th>
<th>Develop Solutions</th>
<th>Implement Solutions</th>
<th>Evaluate Results</th>
<th>Standardize Solutions</th>
<th>Plan for the Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Charts</td>
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<tr>
<td>Check Sheets</td>
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<td>Pareto Chart</td>
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<td>Histogram</td>
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<tr>
<td>Cause and Effect Diagram</td>
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<tr>
<td>Scatter Diagram</td>
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<tr>
<td>Control Chart</td>
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</table>

3. **RECENT APPLICATIONS OF THE BASIC QUALITY TOOLS IN MANUFACTURING, SERVICES AND EDUCATIONAL ORGANIZATIONS**

As it was mentioned earlier, according to Ishikawa 95% of quality related problems in any organization can be resolved using the process improvement approach based on the seven basic quality tools; This important statement can be proven from the amount and quality of research papers and articles published by quality practitioners and researchers especially in the areas of manufacturing and services (Mukhopadhyay and Nataraja, 2004), Sahni, (1998), Gunther and Hawkins, (1999)). It is important to note that these tools are listed under the Body of Knowledge (BoK) in the ASQ Certification Programs. Many conferences organised by quality societies around the world have been devoted to these tools; Just to name the most recent ones:

On the theme: "The Application of Regional and International Indicators of Academic Quality and Accreditation in Universities in the Islamic World- Towards Excellence As a Means Not Merely On Outcome"
• ASQ Southwest Conference, Seven Basic Quality Tools, October 14, 2006, Main theme Back to basics – The 7 Basic Quality Tools: A full description of this event can be obtained from the Standards Newsletter of the measurement quality division of the ASQ at the web link (www.asq.org/measure/pdf/2006-12-the-standard-short.pdf).

• 2005 ASQ/Iowa Quality Centre Spring Conference, April 14, 2005: The conference was organized under the major theme: "Back to Basics", where most of keynote speakers addressed the use of the basic quality tools with the PDCA cycle to achieve process improvement in services such healthcare, education and warranty administrations.

Table 2 summarizes a sample of research articles which show the effectiveness of the basic quality tools in problem solving and continuous process improvement in different organisations. These studies conducted by quality practitioners show that within nowadays competitive environment, manufacturing and service organisations can continuously improve their processes to meet ISO 9000 requirements and achieve breakthrough improvements and business excellence using the basic quality tools together with the deployment of quality awards standards. The benefits gained by organisations fit well with the Deming chain reaction which are quality improvement, costs decrease, productivity improvement, defect rate reduction, customer satisfaction and increased profits. It has to be stressed here that higher education institutions and faculty members can indeed get a lot of benefit out of this basic, simple and cost effective tools in order to improve the educational process. Recent studies presented by Steyn (2000), Blanton (2002) and Marks and O’Connell (2003) show the effectiveness of such tools in improving the educational process in higher education institutions. These studies show clearly that there is no shortage of improvements for educational institutions to work on. However, choosing what to work on and what to improve is the question.

**Figure 3: Systematic Use of the Seven Basic Quality Tools**
On the theme: "The Application of Regional and International Indicators of Academic Quality and Accreditation in Universities in the Islamic World - Towards Excellence As a Means Not Merely On Outcome"
Table 2: Applications of the Basic Quality Tools in Organisations

<table>
<thead>
<tr>
<th>Author</th>
<th>Publication’s year</th>
<th>Application’s Nature</th>
<th>Paper’s Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carla A. C.</td>
<td>1992</td>
<td>Human Resources</td>
<td>Seven basic quality tools</td>
</tr>
<tr>
<td>Sahni, A.</td>
<td>1998</td>
<td>Medical Devices Industry</td>
<td>‘Quality Improvement: Seven Basic Tools That Can Improve Quality’</td>
</tr>
<tr>
<td>Gunther and Hawkins</td>
<td>1999</td>
<td>Service organisations</td>
<td>'Making TQM work: Quality tools for human service organizations’</td>
</tr>
<tr>
<td>Blonton, P</td>
<td>2002</td>
<td>Education</td>
<td>Quality tools in science education</td>
</tr>
<tr>
<td>Herrman</td>
<td>2002</td>
<td>Feed manufacturing</td>
<td>Statistical Process Control : Techniques for Feed Manufacturing</td>
</tr>
<tr>
<td>Gijo and Perumallu</td>
<td>2003</td>
<td>Mechanical Manufacturing</td>
<td>Quality Improvement by reducing variation : A case study</td>
</tr>
<tr>
<td>Marks and O’Connell</td>
<td>2003</td>
<td>Higher Education</td>
<td>Using statistical Control Charts to analyze data from student evaluations of teaching</td>
</tr>
<tr>
<td>Mukhopadhyay and Nataraja</td>
<td>2004</td>
<td>Mechanical Manufacturing</td>
<td>Improvement of Piston Ring Quality : A case study.</td>
</tr>
<tr>
<td>Dias and Saraiva</td>
<td>2004</td>
<td>Manufacturing and services</td>
<td>Use Basic Quality Tools To Manage Your Processes.</td>
</tr>
<tr>
<td>Calabrese et al.</td>
<td>2007</td>
<td>Pharmaceutical Industry</td>
<td>Reducing Variance</td>
</tr>
<tr>
<td>R. Tennant et al.</td>
<td>2007</td>
<td>Healthcare</td>
<td>'Monitoring patients using control charts: a systematic review'</td>
</tr>
</tbody>
</table>

4. USE OF QUALITY TOOLS FOR COURSE IMPROVEMENT: A SIMPLE APPROACH

In this section, the continuous process improvement approach using the seven basic quality tools will be adopted for improvement of an engineering course delivered at the University of Hail as a case study.
An introductory engineering course delivered to first year engineering students at the University of Hail with total number of 536 students enrolled during the first semester 2009/2010. The students were subdivided into 20 sections, each section containing around 25 students.

The PREP004 course intitled “Introduction to Engineering” has as an objective to introduce preparatory year students to the basic concepts of engineering, the engineering profession, including the disciplines of mechanical, electrical, chemical, civil, and computer engineering. The course prepares students for success in their engineering education and their professional careers through the integration of engineering skills such as technical problem solving, engineering design, ethical decision-making, teamwork, and oral and written communications, and Engineering Graphics. This course is a common course for students enrolled in Mechanical, Civil, Chemical, Electrical, Industrial engineering and Management Information system, and computer engineering departments.

In order to study the educational process at the university and identify the major problems and the areas of improvement, the final results of the 536 students enrolled in the PREP004 course were obtained from the registration database and analysed. These included the grades of the PREP004, English course, Mathematics, Physics and the GPA in High School for each student. A preliminary statistical analysis of the students grades revealed the following results:
• A high drop rate of 34.34 percent (with grades DN, WF, WP, W)
• A Failure rate of about 9.2 percent (F).
• A success rate 57.46 percent.

The histogram for the students population presented in figure 4, shows that a high drop rate is present in the course which is considered as a real quality problem in the educational process at the university. Causes should be identified and solved in order to improve the quality at the university especially at the first year. The overall performance of the students who finished the course up to the final stage, is acceptable since the grades were normally distributed from the highest grade ($A^+$) to the lowest one (D). The failure rate represented about 9 percent was considered to be an acceptable rate by the course instructors. However, when examining the results for each section, considerable variability was found between the sections. For example, some sections exhibited an acceptable performance with a normal distribution (figure 5-a) while other sections exhibited extremely poor performance (figure 5-b) and other sections had very good performance (Figure 5-c). This high variability among the sections was considered by the faculty members to be a sign of poor quality and more important this was considered as an area of improvement. It must be mentioned here, that as stated by Deming (1986), process variability is the enemy of quality; It is a disease that threatens all sort of organizations and leadership should understand this process variability and work on the system to reduce and control it.
Figure 4 – Frequency Distribution of the Final Grades of the 536 Engineering students

Figure 5 – Frequency Distribution for different sections

a. Sections with normal performance

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A root cause analysis for the problem identified earlier which concerns the high drop and failure rates in the course, was performed using the fishbone diagram through multiple brainstorming sessions with faculty members and students of the current academic semester. The results of this analysis which is presented in figure 6, revealed that there are many areas of improvement to be tackled in order to improve the quality of the educational process in this area of engineering education at the university. This would include:

- Improving the educator and student contact.
- Improving communication between students and the faculty and the university system through academic advising.
- Improving teaching methods by adopting e-Learning, m-Learning and all new instructional educational methods.
The authors believe that the fishbone analysis would need careful consideration and analysis by decision-makers and leaders at educational institutions as well as by educators themselves since it revealed some hidden root causes for our students failure to catch-up with engineering education especially in Arab countries with similar social habits and culture.

In order to identify the possible relationship between the students performance in the engineering course with other variables such as their performance in English, mathematics, physics courses and their GPA in higher school, scatter diagrams were plotted for each variable. The scatter diagrams presented in figure 7 show a weak correlation between students performance in the engineering course and their performance in English and the other subjects indicating that other causes identified from the fishbone analysis would be investigated further.

4. CONCLUSIONS

Total Quality Management has assisted business organisations to compete in a global market. It is a promising approach for improving various processes, including learning processes, in higher education. This approach aims at continuously meeting and exceeding the needs and requirements of the customer by employing an efficient measurement system which consists of a bench of quality tools and techniques.

The paper showed that understanding the engineering educational process so it can be improved in a systematic and
cost effective approach using relevant quality tools. The paper suggests the use of the seven basic tools known as the magnificent seven (Nankana, 2005) to extract from raw process data very important information for the improvement of the educational process. These basic tools are of graphical nature, very easy to use and very efficient, that any engineering instructor can master easily and use them for improvement. Briefly, these seven tools can help engineering educators and decision-makers at higher education institutions answer very important questions such as:

- The flow chart - What is done? And what are we really doing?
- Pareto analysis – What are the big problems we are facing?
- Cause and Effect Diagram – What are the causes for the problem?
- Histogram – What is going on in our process? What is the nature of the variation?
- Check sheets – How often does it occur?
- Scatter Diagram – What are the relationship between factors?
- Control Charts – Which variations are to be controlled and how?

Figure 6 : Cause and Effect Analysis of the Drop and Failure Rates in the Engineering Course
On the theme: "The Application of Regional and International Indicators of Academic Quality and Accreditation in Universities in the Islamic World- Towards Excellence As a Means Not Merely On Outcome"
Figure 7: Scatter Diagrams of Students Performance

a. Engineering course versus GPA of higher Eschool

b. Engineering course versus English

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