

## How Total Quality Management Can Support Stem Education

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### ABSTRACT

In today's global competitive environment TQM has been acknowledged by industry and services to be a successful managerial strategy in continuously improving organizational performance. During the last 20 years there is a strong debate on whether TQM can be adopted in education. This paper summarizes past experiences in TQM implementation in higher education and discusses issues that need to be faced, in order to recognize the unique aspects of education. Many higher educational institutions have recognized the importance of quality in their field and have begun to apply TQM programs taking advantage of the anticipated benefits that TQM has to offer. STEM (Science, Technology, Engineering, and Mathematics) on the other hand is becoming a very popular concept in education, especially in the United States and the United Kingdom. This paper presents the way the main principles of TQM in higher education can serve the demands and objectives of STEM education.

**Keywords:** Quality, Total Quality Management, TQM, Higher Education, STEM Education

### 1 INTRODUCTION

While TQM is generally accepted in industry and service organizations as a successful managerial strategy, its role in higher education, is still under review and somewhat controversial. During the last 20 years there is a strong debate on whether TQM can be adopted in education. TQM's customer orientation creates problems when applied to universities. Specifically, the student, when viewed as a customer, does not fit the traditional classification of a customer, nor does it encompass the traditional properties of a customer.

Although problems exist in TQM in higher education, they have not significantly diminished its applicability, perhaps due to the given need for urgent change in this area. Financial problems and market pressures, which are challenging many higher education institutions, appear to give the main impetus for change. They leave institutions no alternative but to offer "higher quality at a lower cost" – a primary aim of TQM. As a result, higher education institutions have to develop methods to improve their quality. They have to embrace the concepts of TQM as a means of continually improving every aspect of their organizations.

The anticipated results are similar to those experienced in the manufacturing or service sectors. Namely, higher quality services are delivered both to internal and external customers, increased customer satisfaction, higher productivity, and improved student/ staff morale are achieved.

In the past years, several examples show that quality improvement has been one of the most characteristic features of higher education in many countries. By now, TQM has been accepted by many universities and colleges in the higher education world, in the USA, in the UK, in Sweden, in Finland, in India and other countries (Aly & Akpovi, 2001; Kleindorfer, 1994; Owlia & Aspinwall, 1997; Sahney *et al*, 2004; Swift, 1996; Wiklund *et al*, 2003).

Since the late 1990s several organizations in USA, like the National Science Foundation and the National Research Council have started expressing their concerns on the importance of improving undergraduate education in science, technology, engineering and mathematics (NSF, 1996, 1998). STEM, the acronym that stands for Science, Technology, Engineering, and Mathematics (<http://www.stemedcoalition.org/>) has become a push, started in the United States and spreading over Europe, to promote the value and understanding of the related disciplines and their essential role in addressing today's scientific, social and economic challenges. The urge arises from a perceived deficiency in the West of technically educated people, and thus a wide gap between the United States and developing countries such as China and India. STEM education has its own motives and emphases. Critical is the notion of life-long learning and individual unsupervised learning. These follow the fact that engineering and technologies are in a flux of rapid and frequent change. Unlike some traditional topics, STEM education must be reviewed and updated on a

continual basis. This is a common aspect for both TQM and STEM: the need for continuous improvement, which is the cornerstone of TQM is a prerequisite for STEM education. The TQM philosophy, in general, can serve the demands and goals of STEM education. TQM frameworks for education and the supportive tools and techniques applied can support and supplement on STEM goals and approaches to teaching and learning.

## **2 THE TQM APPROACH IN IMPROVING HIGHER EDUCATION**

The applicability of TQM in higher education has been the debate for many years (Houston, 2007; Srikanthan & Dalrymple, 2003; Stensaasen, 1995; Venkatraman, 2007). As mentioned above, while TQM has been adopted by many organizations world-wide, its implementation in non-profit organizations, such as higher education institutions, presents more challenges and difficulties than those encountered in business organizations. What are the problems of implementing TQM in higher education? Who is the customer? Can we identify the products? Can we specify a customer-driven definition of quality and introduce a management quality culture based on the industrial model in the education environment? What is the role that the students play in their own learning? Can we control and measure processes related to teaching and learning? These are some of the question elaborated by many researchers in the recent years (Adrian et al, 1997; Harvey & Knight, 1996; Michael et al, 1997; Prendergast et al, 2001; Sahney et al, 2004; Sirvanci, 2004; Temponi, 2005; Wiklund et al, 2003; Venkatraman, 2007).

### **2.1 Concepts and Principles of TQM in Higher Education**

Several TQM models exist, that present answers to the above questions. These models, based on the teachings of quality gurus, generally involve a number of “principles” or “essential” elements (Arcaro, 1995, Sahney et al, 2004/2). The main concepts and principles of TQM in higher education are presented below in more detail:

- *Focus on the customer.* Among the essential elements of TQM, customer focus is probably the most important, as reflected by the weight assigned to it by various quality award criteria (Sirvanci, 2004). Customer identification in a higher education institution seems to present more difficulties than are encountered in business organizations. For example in one model interpretation, parents and students could be perceived as external customers to the quality system, while in another, they might be perceived as internal customers. At the same time parents act as suppliers also, since they supply the system with “products” – their children- who are influenced respectively by the family environment. With the term *Internal Customers*, in a TQM program in an education institution, we refer to the parents, students, faculty, administration and staff of the institution. On the other hand, with the term *External Customers* we refer to society, businesses, future employers, families and other institutions that the students might continue their studies, and have an interest in the output of the institution's education process. There is a belief that some of these groups are more like stakeholders than customers and perhaps customers of secondary processes rather than customers of the primary process of education. There are also different viewpoints of different interest groups on who the customers are. For example, while most administrators tend to perceive students as the customers, faculty staff resent this metaphor as being too commercial.

Overall it is important to note that without a well-defined customer and customer focus, quality efforts may easily end up in failure. In TQM it is well known that Quality is defined by the customer; Quality is what the customer says it is. This is the reason, that the definition of the educational institution's customer is such an important and necessary task. Therefore, it is worth mentioning that, one of the critical steps in TQM implementation is the step of *customer identification*, where current and potential customers of the organization are determined.

Except of the importance of defining the *customer*, special attention should be paid to the duality of the students', as well as, the instructors' roles in the institution's quality system. Because of this duality of roles, a more intelligent application of TQM in higher education needs a clearer understanding of the fact that the teacher is not only a supplier as the student is not just a customer (Meirovich and Romar, 2006).

- *Commitment.* Top Management's leadership and commitment to quality is also one of the essential elements of TQM. Management's commitment is a prerequisite in order to start any quality initiative. Quality needs a change of culture and given that people resist to changes, management's commitment is an essential element for success. This commitment to quality has to be proven in practice, top leaders need to “walk the walk and talk the talk” in order to teach by example and direct involvement. Commitment to quality can also be proven by the allocation of sufficient resources and time. By the term “resources” we refer to people, tools, training and processes that will boost and promote quality. In education institutions the issue of leadership differs from the typical leadership in a business organization. Presidents, chancellors or deans do not enjoy ultimate authority as the CEOs of business organizations. Depending on the country, the administration and governance of the university might be shared. This leads to diffusion of authority and responsibility, and, as a result the top administration lacks the authority to undertake drastic measures and changes in higher education institutions. University presidents and chancellors, as leaders, can naturally set goals, organizational values and performance expectations. However, since they lack the necessary authority, it is difficult to deploy these values and goals through the layers of the higher education institutions

(Sirvanci, 2004).

- *Total involvement.* Another crucial element in TQM in education is the involvement of all interested parties, mentioned above, in the educational reform. Quality is the responsibility of every member of the organization rather than the responsibility of the “administration”, or the equivalent of a quality department in industry. Changes are an outgrowth of faculty involvement rather than those of the university administration. It has to be noted that the involvement of *all* interested parties is a *crucial* element for success.
- *Measurements.* “You cannot improve what you cannot measure” is a well-known saying. Measurement against defined goals is a very important element for the successful implementation of a TQM program in an educational institution. In order to prove success, an institution must define quality objectives, measure the starting point of the quality effort, and use measurements for proving the attainment of improvements. A possible problem that may appear is to focus on problem solving, without, at the same time, measure the effectiveness of these efforts. Accomplishments need to be measured, and furthermore, communicated to the whole of the organization to support continuity in the quality improvement effort.
- *Continuous improvement.* Given the principle “Do something tomorrow better than you did it today”, the goal of every TQM effort is continuous improvement. TQM is a continuous, unending process of improvement. The TQM program should be reviewed and evaluated on a regular basis to ensure goals are still focused and objectives are being met. In the continuous improvement process small improvements are important, as well as, great improvements. Faults and problems are opportunities for further improvement and in no case openings for criticism or judgments. In a TQM program everybody is responsible for preventing and solving problems. TQM is a philosophy of never ending improvements achievable only by people. Furthermore, continuous improvement in academic institutions means exploring the needs and expectations of the institutions’ customer base, re-evaluating the effectiveness of programs and total quality initiatives (Temponi, 2005).

## 2.2 Implementation Models for TQM in Higher Education

For implementing TQM in higher education, several models exist that present answers to the above mentioned questions. Some of these models are based on:

1. TQM principles and essential elements, described above
2. The teachings of the famous quality gurus (such as Deming, Juran and Crosby), and
3. The existing criteria of the quality awards, such as the Malcome Baldrige National Quality Award (MBNQA) in the USA, the European Quality Award (EQA) and the Deming Award in Japan.

In literature, there are also many examples of TQM models for higher education, which have been used by several universities in the United States that are considered to be the leaders of TQM in higher education. The examples of the Oregon State University, the Harvard University, the University of Wisconsin-Madison, the Babson College, Fox Valley Technical College, and the Northwest Missouri State University can be found in the paper presented by Michael et al. (1997). Also the implementation examples of two California public higher education systems are presented by Aly & Akpovi (2001) in their paper, as well as the implementation of TQM in the University of Pennsylvania (Kleindorfer, 1994). Another implementation framework for implementing TQM in higher education programs is presented by Venkatraman (2007).

As can be seen from many of the examples of implementing TQM in higher education, in general, the character of implementation is still limited to business-type operations in universities, such as business, finance and administrative services (Aly & Akpovi, 2001).

Nevertheless, TQM in Education can be seen by different perspectives and can be applied at three levels:

- The first level is to the administrative and management processes of an educational organization, with benefits in improved efficiency and lower costs.
- The second level is teaching TQM, the quality philosophy, methods and tools to students.
- The third level is total quality in the learning process. This has to do with a learning philosophy supported by a comprehensive tool kit and driven by students and staff in order to identify, analyze, and remove the barriers to learning (Hansen, 1993; Venkatraman, 2007).

Implementation of TQM can start at any level and progress further in other levels gradually.

It is important to keep in mind, that although, many models exist, models should serve as a basic foundation for colleges and universities to follow when they implement TQM in their own institution. The model that will be

chosen needs to be tailored to suit the institutions individual needs. In many cases, universities choose a combination of models in order to cover their special needs.

TQM was first introduced into higher education in the USA, followed by UK institutions. Based on a research contacted by Owlia and Aspinwall, it can be seen that in the USA, total quality practices seem to be more extensive and more widely accepted than in the UK. This can be explained by the more privatized and market-dominant nature of US higher education, in comparison with the more traditional UK universities, which usually rely on their national and international reputation (Owlia & Aspinwall, 1997).

### 2.3 Barriers and Obstacles to a Successful TQM Implementation

In order to have a successful implementation of a TQM program, there is a list of things to do and problems and pitfalls to take care of and avoid.

On the one hand, the things that one can do, in order to improve success chances are presented below:

- *Leadership.* Top leadership is the driving force behind success. The program leader must have top management's full support and teach by example. Top management's direct involvement is a key to the program's success.
- *Commitment to the principles of TQM.* It takes years in order to drive the principles of TQM through to all employees and students; emphasis on training can help. A basic ingredient for the success of the TQM effort is the commitment of the leadership of the academic organization.
  - *Customer focus.* As discussed above it is really important to clearly identify all customers in the educational quality system and focus on the primary customer of the process in question.
  - *Evaluation.* Measurement and evaluation efforts are needed in all aspects of the TQM effort. The introduction of fact-based management and measurement help in convincing about the efficacy of TQM.
  - *Resources.* It is very important to allocate sufficient resources and time to the quality effort. Caution has to be given in order not to underestimate the faculty and staff resources required to launch a TQM effort. TQM needs time, persistence and patience in order to succeed.
  - *Training.* As mentioned before training can make a great difference. Training for management and staff, academics and students, in order to understand the philosophy of TQM and acquire the necessary skills for teamworking.
  - *Empower.* A TQM program cannot be forced on "employees". Leadership must convince employees to accept the program and participate voluntarily. Employees must be empowered and willing to follow the TQM program and believe in its necessity. Note that students are also "employees" in a TQM program in education they also need to be empowered and persuaded.
  - *Quality Model.* Models are a good starting point, but no model is perfect for every university. The chosen model needs to be tailored to suit the individual needs of the institution.
  - *Starting Point.* Starting with a department where success will come more easily and quality improvements will be clearer to present is a good tactic. Usually administration is the first area to be subjected to quality and scientists only join the effort much later. Academia will be easier to follow once success is already proven. Nevertheless, there is a need to achieve faculty commitment to quality.
  - *Communication.* The issue of internal communication, but also communication outside the organization to the community, is very important for the success of the TQM effort. The dissemination of information helps getting all interested parties involved in the institutions success.

On the other hand, the things that one can avoid and take care of, so that the whole effort will not end in failure are presented below:

- Believe that TQM is a "quick fix" and anticipate benefits immediately. Impatience leads to disappointment.
- Not exhibit top management's commitment by example.
- Fail to adapt business principles correctly to an academic environment.
- Fail to address organization structure issues that create problems in focusing on a shared mission or common goal.
- Avoid empowering employees because leadership is unwilling to do so.

- Fail to estimate correctly the necessary resources (faculty and staff resources, time and capital).
- Not provide sufficient training and knowledge to all interested parties.

### 3 HOW CAN TQM SERVE THE GOALS OF STEM EDUCATION?

According to Labov et al. (2009) STEM education has many different learning goals. STEM goals include the following:

- Mastering a few major principles/concepts well and in depth (as distinct from procedural knowledge)
- Long-term retention of what is learned
- Building a mental framework that serves as a foundation for future learning
- Developing visualization competence including the ability to critique, interpret, construct, and connect with physical systems
- Developing the analytical skills and critical judgment needed to use scientific information to make informed decisions
- Understanding the nature of science
- Finding satisfaction in engaging with real-world issues that require knowledge of science.

The above mentioned goals are compatible and could easily be applied in parallel with TQM goals in Education, especially in the case that the educational organization decides to fully implement a TQM program and apply quality principles in the learning process (applying TQM in classroom). STEM education could benefit from the lessons learned from previous TQM program experiences and use the same tools and techniques in achieving its goals.

In fact, compared to general education, there seems to be more opportunities for STEM to benefit from TQM. This is due to three main observations: It is of paramount importance that STEM requires the commitment of top administration, STEM requires the positive changes in institutional culture towards the delivery and instruction of the technical content, and finally, STEM requires a fully competent faculty who can exceed the traditional boundaries of education.

More precisely, the ways that STEM can benefit from TQM are presented below, in relation with TQM main principles and lessons learned:

- *Continuous Improvement.*

First and foremost, STEM must embrace change, as rapid change is a given in technology and engineering. TQM's experiences in change management could prove to be very valuable for STEM, since TQM is also based in a change of culture which in turn must be communicated throughout the whole of the organization.

In this respect, the lessons of TQM, especially as they are viewed by high-technology firms where rapid change is a way of life, are most appropriate to STEM education. After all, STEM also involves the same rapidly changing technologies as those experienced in industry.

Furthermore, the above mentioned need, forces STEM education to be continuously reviewed and updated. As mentioned before, continuous improvement is a cornerstone of TQM, thus STEM can benefit from TQM experiences, as well as, the tools and techniques applied in TQM for achieving its goal.

- *Customer focus.*

Especially in technologies and engineering, STEM education must always keep the pulse of the customers who will use the "end product"; in this case, companies and institutions that will employ the graduates of STEM education. As the technologies change, so do the needs of the employing agencies. This in part comes from rather complicated dynamics. As technologies change, they are embraced by society. As a result, the way society uses or embraces certain technologies affect future demands. This in turn gives rise to changes in direction for STEM education. STEM education would be successful if the key principle of customer focus is emphasized and continual information feedback is provided to the educational institution. This could be done by formal visits, industrial review or steering, or by the direct involvement of the educational institutions in commercial and industrial activities. Tools and techniques used in TQM programs for continuous improvement and focusing on the customer can directly serve to the above need.

- *Leadership Commitment.*

It is important that educational leadership understand and be competent in STEM topics. It is no longer

acceptable that a professor teaches a technology which he is unable to produce. For example, it is insufficient for a professor to teach a programming language unless the professor has written a compiler for that language. This is a tall order that goes against the adage that “those who can, do, those who cannot, teach”. Not having total commitment from top management, in this case, deans, chairpersons, and professors, will hamper the effectiveness of STEM education.

- *Total Involvement; No Quick Fix.*

TQM indicates that successful STEM education cannot be implemented by a simple change in curricula and the teaching environment. All elements of the system, including academic administration and the faculty must be committed as well as well rehearsed in the subject matter and philosophy of STEM. The principles of total involvement and teamwork that TQM promotes are definitely going to serve STEM goals.

This is a particularly delicate issue, as tenured faculty members are often resistant to change. The university as an institution is often seen as a conservative body where change is slow. Such prudence protects the institution from a mercurial stance. However, neither must change be placed on a slow track which will disallow the institution to miss the developments in technology. The key is to follow the rapid technological advancements while allowing time for the institutional processes to digest the fundamental modifications that are necessitated by STEM education.

All involved parties need to understand that STEM, like TQM, will be no quick fix, it needs time, patience and persistence to achieve success.

- *Change of Culture.*

STEM education would follow TQM in benefiting from a change of institutional culture and traditions. The members of a STEM education system should be committed to the goals of STEM and be competent in their respective fields. This requires a total commitment, that is, a partial implementation of STEM will be open to future difficulties and systemic failure.

Cultural changes in large institutions are usually slow, due to the low turnover in faculty and staff. Even student presence typically has a four year lifespan from being admitted to graduation. Nonetheless, cultural changes are necessary for the emphasis of STEM to be fully implemented.

#### **4 CONCLUSIONS**

Higher education institutions have been facing challenges for some time and are expected to face more in the future. In the new environment that higher education has entered quality plays an increasingly important role. Feigenbaum (1994) believes that “quality of education” is the key factor in “invisible” competition between countries since the quality of products and services is determined by the way that “managers, teachers, workers, engineers, and economists think, act and make decisions about quality. Higher education is being driven towards commercial competition imposed by economic forces (Owlia & Aspinwall, 1997). The new situation demands higher quality at lower costs, together with improved efficiency. Despite opinions that regard TQM as “the latest in a series of fads urged on higher education” it seems that there is solid reasoning behind introducing Total Quality philosophy in universities. TQM is seen by many as having enormous potential to respond to the challenges.

STEM education is a relatively new push in developed western societies. We argue that the successful implementation of STEM would greatly benefit from following the principles of TQM.

In particular, there is a need for top university administration to be committed to STEM education and undertake the necessary steps to establish the institutional culture within which the push for STEM could be successful. It should be understood that such a shift requires a long-term commitment from both the administration and the staff. The establishment of adequate performance measures, along with the periodic evaluation of the venture is a prerequisite for the success of the program. The elements and requirements associated with STEM education, in this respect, are very much aligned with TQM and its experience from similar cases in manufacturing and service industries.

Lastly, STEM education will benefit from competent faculty members who have actual experience outside the realm of teaching and research. This experience is necessary for the educators to more effectively take on the role of mentors, who can relate to actual field experiences, rather than to be mere tutors who are familiar with the topics but unable to provide further insights. Just as TQM promotes a competent workforce totally involved in the continuous improvement effort, faculty with a wide range of experiences is most desirable in STEM education.

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