A QUEST FOR WASTE REDUCTION AT INSTITUTIONS OF HIGHER LEARNING: INVESTIGATING THE INTEGRATION OF SIX SIGMA AND LEAN SIX SIGMA METHODOLOGIES WITH TOTAL QUALITY MANAGEMENT

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ABSTRACT

Institutions of higher learning are required to rethink strategies to eliminate "institutional waste". The sector is facing numerous challenges with resource restrictions. Factors such as the impact of the Fees-must-fall campaign in South Africa and the global tendency of government initiatives to increase student enrolment targets, while subsidies, on a continual basis, are on the decrease, places institutions in higher education under enormous financial distress. This article argues that the majority of institutions' quality management systems in South Africa and abroad are underpinned by the principles of Total Quality Management (TQM). There is a dearth of research on the implementation of Six Sigma and Lean Six Sigma in higher education. This article investigates the integration of Six Sigma and Lean Six Sigma as mechanisms to reduce waste in the higher education sector. It reflects on how this integration can enhance a university's core business and institutional functions through processes of continuous quality assurance, the latter is characteristic of the principles of TQM.

Keywords: quality management, Six Sigma, Total Quality Management, waste reduction, Lean Six Sigma

INTRODUCTION

The viewpoints of theorists and scholars that the article refers to, may follow mainly a neoliberal approach to finding solutions to address waste reduction in the higher education sector. However, the views and opinions expressed in this article are not intended to follow any particular paradigm per se, nor are they meant to be prescriptive as the only solution to waste reduction. Given the dearth of research on this topic, the choice of selecting literature was limited.

Globally, the decline of government subsidies to public institutions, as a result of the impact of economic recession, requires from universities a rethinking on ways to reduce cost. This article argues that institutions, therefore, should develop strategies to eliminate

institutional waste. Waste in higher education can be regarded, amongst others, as repetition of topics already taught in other courses, spoon-feeding, the teaching of outdated course material and the waiting for unprepared students to catch up (Taitkonda 2007). It is a global tendency, with regard to institutions of higher learning that a quality gap has developed as a result of governments' initiatives to increase the numbers of student enrolments, while they continuously decrease investments (Vroeijenstijn 1995, 3). In South Africa, the Fees-must-fall campaign brought institutions to a standstill in 2015 (Essop 2016, 4). During this campaign, students demanded free education, which put the majority of institutions of higher learning under financial distress.

For institutions of higher learning "to do more with less" (Shah 2009, 134), places a high demand on the fitness of institutional quality management systems to offer affordable education and ensure continuous improvement of its core business. There is an "enormous waste of scarce financial resources" due to the fact that about 45 percent of an entering undergraduate cohort drops out without a qualification and of "those that graduate, just under half take five or more years to do so" (Essop 2016, 4).

The notion of waste reduction in higher education is not a familiar concept. In this article, waste can be defined as "anything in the process that does not add value for the customer" (Foster 2007, 87). Maguad (2007, 248–255) states, "educational work is a process, waste can come from many areas within this process". As receivers of revenue, public institutions of higher learning have to be more accountable; this places a high demand on effectiveness of institutional quality management systems, which will have "a positive effect on revenue" (Shah 2009, 129).

There is, therefore, a direct relation between quality improvement and financial prosperity. Cutting costs through increased efficiencies can enhance an institution's profitability. Shah (2009, 134) states that in finding way to "to more with less", institutions of higher learning could identify areas for potential savings, for example to eliminate redundant institutional activities, simplify organisational structures, decentralise services and restructure administrative services (Kiley 2011). Modern higher education, to a great extent, are commercialised organisations that behave like businesses in their management processes (Mazumder 2014). It is not an unfamiliar practice for universities to apply quality management models, concepts and techniques, such as TQM, that originate from the industrial environment (Meirovich and Romar 2006, 325; Saunders and Walker 1991, 91–103; Anyamele 2005; Willis and Taylor 1999, 997–1007; Cruickshank 2003). According to the quality guru, Deming (1993), the education system can be enhanced by introducing the principles that are used in industry to improve their systems and processes by aligning them with performance and cost objectives.

Many institutions of higher learning developed quality management systems that are underpinned by the philosophy and principles of TQM (Brits 2010), which place a high demand on customer satisfaction. TQM, therefore, can be regarded as a customer-focused management system. An institution of higher learning that developed a quality management system, underpinned by the TQM approach, should be able to address the needs and expectations of its primary customers (staff and students) by improving institutional processes and reducing waste and cost.

The above-mentioned global rising of the cost of higher education and the increasing pressure from its customers to provide quality education (Cruickshank 2003, 1160), compels universities to adopt models of profit-making organisations. Institutions should find ways to enhance their processes by determining which add value and which do not. Raifsnider and Kurt (2004, 3) suggest the implementation of Lean Six Sigma (or Six Sigma and Lean Six Sigma) to improve institutional processes. Lean Six Sigma helps organisations get a competitive advantage by becoming better and more cost effective, while Six Sigma helps to detect deficiencies that will deliver outcomes that meet the needs and expectations of the customer (Simons 2013, 1).

According to Raifsnider and Kurt (2004, 3), Lean Six Sigma eliminates waste or non value-added activities or steps (Antony et al. 2012) while Six Sigma focuses on financial results. Six Sigma is a methodology to reduce variation within a business process (Antony et al. 2012, 941). In the private sector, Six Sigma creates enormous savings and increases profits as a "leading business strategy" (Goffnett 2004, 2). Institutions that integrate elements of Six Sigma and Lean Six Sigma will be able to achieve quality of institutional processes without waste. Institutions have numerous processes, each with an expected degree of variation. In his study, Mazumder (2014) argues that universities should determine what constitutes normal variation so that it can be projected, his study also reveals that the degree in which process variation can be reduced and controlled, the more accurately will the process results be predicted. Lean Six Sigma blends the Lean approach with Six Sigma. Lean Six Sigma uses Six Sigma methodologies, focuses on process speed, the enhancement of process flow and, as already mentioned, the reduction of waste.

There is a dearth of research on the implementation of Six Sigma and Lean Six Sigma in higher education. This article argues that the effective enhancement of these processes will result in customer satisfaction, which has a direct impact on institutional cost and waste. It investigates the feasibility of the integration of Six Sigma methodologies, including Lean Six Sigma techniques, to quality management systems in the higher education sector. As already mentioned, the majority of higher learning institutions in South Africa have quality

management systems that are based on the principles and methodologies of TQM. The article gives a critical reflection on the implementation of Six Sigma and Lean Six Sigma methodology in an educational environment as a strategy to reduce waste and to ensure ongoing improvement.

QUALITY MANAGEMENT

The notion of accountability management in the public sector is high on the agenda of higher education institutions. Although, traditionally universities are not viewed as profitable organisations, they are accountable to develop and implement effective quality management systems (Loder 1990, 2). The public demand that universities should be held accountable for receiving scarce resources, the impact of the Fees-must-fall demands and the pressure on institutions to do more with less, necessitates universities to find ways to reduce waste, to ensure customer satisfaction and to stay financially sustainable. Van Vught (1996) identifies two approaches of quality management, *inter alia* evaluation and comparison of study programmes with the aim to improve the quality of academic programmes and a focus on the institutional mechanisms and procedures that are in place at an institution for the purpose of self-evaluation.

The following characteristics of effective quality management (Liston 1999, 53) are relevant for the purpose of this article:

- planning, innovation and strategies to implement change
- use of benchmarks, standards and key performance indicators for monitoring change
- evaluation of best practice for continuous improvement
- efficiency and cost-effectiveness
- relational management information systems and reporting mechanisms
- dissemination of information and ongoing communication.

TOTAL QUALITY MANAGEMENT (TQM)

Like many quality management models, TQM developed from the industrial environment and is based on the views and philosophies of quality sages such as Deming, Juran, Ishickawa and Taguchi. The TQM model can be described as processes that collect, analyse and act on stakeholder/customer information on a continuous basis. An important element of TQM is its customer centeredness and the importance of participation of all internal stakeholders or primary customers in the process of quality enhancement. The leaders of an organisation are viewed within the TQM approach as the drivers that are responsible for the development,

implementation and refinement of all quality activities. They empower the members of an organisation and allocate sufficient resources in order to ensure that the plans on all levels can be implemented in order to reach organisational success.

According to Oakland (1998, 18), it is imperative for an organisation to be "fully effective, each part of it must work properly together towards the same goals, recognizing that each person and each activity affects and in turn is affected by others". This emphasises the influence of systems thinking as the underpinning theory of TQM. System theory declares that all systems are governed by the same laws of logic (Higgs and Smith 2006, 28). A gap that exists in many quality management systems is the development and implementation of statistical techniques (Youssef et al. 1998, 584–593). Statistical process control in higher education includes the analysis of a huge amount of data including enrolment figures, graduation rates, retention rates and so forth (Mazumder 2014). Institutional data (metrics) can provide important management information, which can help institutions to reduce waste and errors. This will enhance customer satisfaction and, as a result, save an institution on costs. According to studies conducted by Shah (2009, 125–141), Rust, Moorman and Dickson (2002, 7–24) and Easton and Jarrell (1998 2, 253–307), there is a strong link between enhanced quality, customer satisfaction and higher returns on investments. In due course, quality enhancement results in satisfied customers that are willing to pay more, giving positive publicity and creating a sense of loyalty to the organisation. Therefore, "an emphasis on quality improvement by an institution of higher education will have a positive effect on revenue" (Shah 2009, 125–141). Cutting costs through increased efficiencies could enhance an organisation's profitability. This approach is important, especially for institutions that are facing the impact of massification of higher education, the impact of the Fees-must-fall demands and the dilemma of finding mean.

The value of applying TQM principles in complex organisations such as universities should not be underestimated, as many universities have succeeded in increasing their competitiveness and financial results through the implementation of TQM viewpoints (Motwani and Kumar 1997, 131–135). Unfortunately, it is true that many failed in this regard (Allen and Kilmann 2001). Some scholars regard TQM as the most important management system to education reform (Mehrotra 2010, 1). There are also skeptics such as Koch (2003, 332), who opines that the impact of TQM on higher education is "relatively small" since it focuses too much on non-academic activities and, therefore, makes little or no contribution to academic enhancement. Contrary to this view, the study of Brits (2010, 249–251) emphasises the successful implementation of TQM principles at prominent universities in South Africa, not only for improving non-academic functions but also for the enhancement of academic quality.

SIX SIGMA

There is a tendency amongst institutions of higher learning to be sceptical towards the implementation of quality management models and mechanisms for the sector because they usually originated from the industrial environment. During the 1980s, engineers in the Motorola corporation discovered the "mathematically derived point where the cost of eliminating a defect is greater than the cost of living with (and repairing) the defect" (Raifsnider and Kurt 2004, 4). There is an acceptable point of imperfection and any quality enhancement beyond the imperfection point, which is more expensive than the expected cost savings of repairing the deficiency. The notion of Six Sigma flows from earlier quality viewpoints on what should be considered to produce quality results. The performance target for Six Sigma is a defect-free process. Motorola set up a scale to evaluate the quality of a process based on defect calculations. The acceptable level of imperfection is Six Sigma, *inter alia* to balance quality and cost equates to 3.4 defects per million units, which in turn equates to 3.4 DPMO or 99.9997 percent defect-free. This means that defects are almost eliminated or products are nearly perfect.

Motorola succeeds cost-efficiently to perform defect-free more than 90 percent of the time and savings to the company to date are as much as US$16 billion. Six Sigma is a new management philosophy that is comparable with TQM principles. The intent of Six Sigma is to enhance customer satisfaction by reducing service and process defects and it has transformed many organisations to become more profitable. Six Sigma succeeds in addressing the needs and expectations of the customer (Drake, Sutterfield and Ngassam 2008), which is on par with the principles of TQM.

DMAIC PHASES

Robert Galin first implemented Six Sigma's quality improvement model (Bandyopadhyay and Lichtman 2007, 4). It has five phases for problem solving, *inter alia* define, measure, analyse, improve and control (DMAIC). During the define phase, the current state, problem statement and desired future state, are determined. All information that provides a clear view of the current state, at all levels of the institution, should be gathered and captured. This includes all human-, technology- and process-related information (Raifsnider and Kurt 2004, 7). During this phase, questions can be asked such as what the current problem is, what are the expected results in order to solve the problem, how will you know when the problem is solved and how will success be measured? As an example, within the academic environment, the reduction of waste can be achieved by means of focusing on issues such as improvement initiatives to store documents and to enhance the accessibility of them (Raifsnider and Kurt 2004, 6). The problem statement that is developed during this phase will be refined during the future phases as a result of the

information that will be gathered.

The second phase is the measure phase during which quantitative and qualitative data is gathered. This information and data form the foundation to assess potential solutions. Interviews with stakeholders and process mapping can be conducted during this phase. Typical information that is related to time, volume, frequency and impact is captured. The data and information that were gathered during the measure segment are studied during the third phase, which is characteristically an analysis phase. During this phase, blockages and opportunities for quality enhancement are identified and the non value-adding tasks are removed.

Costs and benefits such as satisfaction and productivity are taken into account. During this phase, technological tools such as a "Value Stream Map" can be applied to understand current processes and to identify deficiencies followed by an improvement phase. The latter includes the finding of solutions and implementation of strategies that will address the identified deficiencies. This phase consists of the implementation of a pilot programme, new technologies and processes that are more streamlined and, eventually, an institution-wide implementation. The control phase consists of mechanisms to monitor improvements. Key metrics are used to evaluate the progress made with regard to the implementation of the remedial plan. During this phase, continuous evaluation and feedback on the successful implementation of initiatives are made to all decision-makers. The DMAIC methodology aligns, to a great extent, with the TQM models and variations for continuous improvement, namely amongst others, plan-do-check-act (PDCA) and plan-implement-review-improve (PIRI).

LEAN SIX SIGMA

Many organisations embarked on Six Sigma and integrated Lean Six Sigma techniques in order to ensure "superior improvement" (Antony et al. 2013, 941). As an example, Lean Six Sigma focuses on "using the minimum amount of resources (people, materials and capital) to produce solutions and deliver them on time to customers" (Raifsnider and Kurt 2004, 5). Lean Six Sigma is the application of lean techniques with the abovementioned Six Sigma methodologies (DMAIC) in order to increase speed and to reduce waste. Six Sigma focuses more on the enhancement of quality and the "Voice of the Customer" (Raifsnider and Kurt 2004, 5), while the focus of Lean Six Sigma is, as already mentioned in this article, on the removal of anything in the process that does not add value. The notion of lean refers to "absence of waste" (Maguad 2007, 250) or the elimination of "different forms of waste or non-added activities or steps" (Antony et al. 2012, 940). A number of principles underpin the philosophy of lean, *inter alia,* the customer determines value and the activities that add no value to the process of customer satisfaction are removed or reduced. As the process is more streamlined, it eventually results in

less waste and costs and a higher level of customer satisfaction. The people that are closest to the work are the ones that are in the best position to improve it; this places the emphasis on teamwork and the training of staff members.

First, an institution of higher learning can introduce the philosophy of Lean Six Sigma by identifying the areas of waste. Secondly, it should find ways to reduce or eliminate the waste. Thirdly, it should develop minimum standards for the processes. Maguad (2007, 248–255) gives examples of typical areas at a university where Lean Six Sigma can be utilised. Maguad mentioned that a university should determine when and where errors occur and then identify the root causes for the errors. An institution of higher learning can apply tools and mechanisms such as a value stream mapping. A value stream map is created to document the flow of resources from supplier to institution. A value stream map "requires flowcharting of processes to determine where customer value is created and to identify non value-added processes and steps which contribute to waste" (Maguad 2007, 252).

Processes can be streamlined by means of flowcharting exercises. Unnecessary steps can be eliminated in this process (for example, too many signatures). Institutions can establish and equip Kaizen-type teams; Kaizen teams use Shewhart's PDCA approach for problem solving. Teamwork, such as Kaizen, is an essential part of ongoing improvement in Lean Six Sigma environments. The following Lean Six Sigma tools and techniques are relevant and can be used in an education environment (Antony et al. 2012, 946):

- Process mapping/value stream mapping: Members understand value in relation to customer satisfaction and where waste occurs.
- Cause and effect analysis: Possibly identify and explore the possible causes related to a problem in order to determine its root causes. Cause and effect analysis is used during brainstorming exercises. Causes may range and include human resources, machines, methods and materials, etcetera.
- Pareto analysis: This method can be used to separate the few causes from the trivial many (the 80/20 rule, *inter alia* 80 per cent of the problems are due to 20 per cent of the vital causes of factors).
- Visual management: This tool is powerful tool as it helps one to understand work priorities, show standards, identify work flow and what is being done and to communicate what performance measures are in place.
- Project charter: This tool provides an overview of the project and serves as an agreement between management and the Lean Six Sigma team regarding the project outcome. This tool is used in the define phase of the Lean Six Sigma methodology.

- Rapid improvement workshops: These workshops are focused on processes (for example, in a department) in order to address some of the problems or issues within the timeframe of the workshop (three to five days). This exercise ensures engagement of participants in change processes, decisions can be made rapidly, cross-functional teams of managers and staff members can work together to solve a problem and the focus is on practical and realistic solutions.

The integration of Six Sigma metrics with TQM provides a measure of comparability that can feed into process enhancement initiatives (Cheng 2009, 313). The integration of Six Sigma methodologies with a TQM approach, supplies a quality management system with statistical tools to achieve measurable objectives, which include enhancing efficiency, productivity, products and processes (Cheng 2009, 313).

In essence, Six Sigma is an extension of TQM, therefore, Six Sigma and Lean Six Sigma methodologies can be integrated into an existing TQM approach without major disturbance in the quality processes of an institution.

According to Simons (2013, 2), Lean Six Sigma has numerous benefits for the higher education sector, amongst others it provides a template for problem solving (DMAIC), promotes total involvement (multiple institutional functions are involved in applying the methodology, which enhances collaboration and counteracts silo management), it obtains information from customers (customers are regarded as any individual or department that receives an output from another department or individual) and it helps to identify and reduce hidden costs. Hidden costs consume resources and time and add little value to the needs and expectations of the customers.

IMPLEMENTING SIX SIGMA (AND LEAN SIX SIGMA) WITHIN AN EDUCATIONAL ENVIRONMENT

Six Sigma methodology (DMAIC) can be effective in solving university processes where the solutions are unknown or the root causes are not determined, whereas Lean Six Sigma is an improvement methodology that is suitable to solve inefficient and ineffective university business processes (Antony et al. 2012, 941). In an institution of higher learning, Six Sigma's data root-cause analysis can facilitate and accelerate process enhancement. Therefore, it can complement existing TQM activities at institutions that focus on the improvement of processes. Continuous improvement models such as PDCA have phases in which techniques are used that resemble the steps of DMAIC methodologies.

Therefore, institutions that are already implementing continuous improvement models that

are based on TQM models will find it relatively easy to integrate Six Sigma and Lean Six Sigma methodologies. This integration can reduce waste and increase proficiency. The study that Revere and Black (2003, 377–391) conducted within a healthcare environment, supports the implementation of Six Sigma with TQM as a mechanism to reduce institutional waste: "Six Sigma can take TQM to the next level, a level with reduced medical errors and increased profitability" (Revere and Black 2003, 379). Cheng (2009, 312–313) states that "implementing Six Sigma does not require that TQM activities be abandoned, rather Six Sigma is just a new philosophy that extends TQM efforts by using detailed metrics to identify and eliminate process variations".

The implementation of Six Sigma and Lean Six Sigma, like the implementation of any quality management principle in the education environment, may be introduced with a certain degree of scepticism amongst academics. Sceptic academics may view it as just another new management trend that originates from the industrial environment that will not succeed to make an impact on the quality in an educational environment. Contributing factors for scepticism are issues such as the focus on customer participation (and the debate on what constitutes the concept "customer" in a higher education environment, which demands a re-defining of the concept), team work, fear of change and fear of added responsibilities for an already overburden academic staff component.

Unfortunately, relatively little information exists about the influence of the implementation Six Sigma in the academic environment (Jenicke, Kumar and Holmes 2008). Scholars such as Jenicke, Kumar and Holmes (2008, 454–455) emphasise the following challenges of the implementation of Six Sigma in higher education:

- The definition of the concept "customer" within the context of higher education
- Difficulty in measuring quality and analysing data
- Limitation of academic reward systems
- Influence of uncontrollable factors on student-, staff- and institutional success.

The implementation of Six Sigma and Lean Six Sigma requires appropriate training of management, established team leaders and teams. Staff should know how to "reallocate their time and energy to studying their processes in teams, searching for causes of problems and correcting the causes, not the symptoms" (Oakland 1998, 19). Kwak and Anbari (2004, 708–715) argues that "training is a key success factor in implementing Six Sigma projects successfully and should be part of an integrated approach, the belt program should start from

the top and be applied to the entire organization". Six Sigma training should cover the strategic steps of DMAIC. Teams should be trained to understand general management processes and how to use statistics in order to make mathematical calculations (Hargrove and Burge 2002). Six Sigma and Lean Six Sigma can only be introduced at an institution of higher learning if the top management endorse this implementation (Jenicke, Kumar and Holmes 2008, 453). Oakland (1998, 20) states, "the most senior directors and management must all demonstrate that they are serious about quality". The role of middle management should also not be under estimated, they must understand the quality management system and demonstrate their commitment to their subordinates.

Jenicke, Kumar and Holmes (2008, 453) emphasise the importance for top management to undergo Six Sigma training, as it is encouraging to other staff members. A concern in this regard is that it is highly unlikely that a senior manager of a university will have sufficient time to attend the Six Sigma training programmes. This might also occur on operational level. Therefore, the implementation of Six Sigma methodologies, the establishment of teams and the training of the members may result in forms of resistance because of the fact that academic staff are already overburdened with administrative issues; the implementation of Six Sigma and Lean Six Sigma may be viewed as initiatives that will add to academics' existing workload.

Moreover, as already mentioned in this article, Six Sigma is a statistically-based process improvement method and focuses on statistical measures of process capability and variability. In an educational environment, there are many influences that are beyond the control of the academic system and not easy to be quantified, as opposed to within the manufacturing environment, such as motivation, family background and finances. The availability of statistical data that is reliable is imperative for the implementation of Six Sigma, as it underpins the statistical methods that an institution will use to reduce variability. Therefore, an institution of higher learning that attempts to introduce Six Sigma methodologies should have systems and structures in place that provide reliable statistical data for the purpose of data analysis and continuous improvement initiatives.

Besides the abovementioned requirements and concerns for the implementation of Six Sigma in higher education, the value of Six Sigma and Lean Six Sigma should not be underestimated. Six Sigma is a statistical tool that institutions can use to increase profits, reduce costs and improve quality by means of a structured system approach to problem solving (Pryor et al. 2008). Six Sigma can be applied to improve the educational process by measuring an institution's effectiveness and quality through numbers of freshman applications, student retention rates, job placement rates, starting salaries, number of publications and presentations of staff on national and international levels (Jenicke, Kumar and Holmes 2008, 461).

At universities, performance indicators can be developed for each organisational level by means of the application of Six Sigma methodology. A concern for many institutions of higher learning is student success rates, which include dropout and throughput rates. Although there is relatively little evidence available on the integration of Six Sigma methodology within academia, scholars such as Hargrove and Burge (2002) conducted studies by using Six Sigma methodologies to address the problem of improving student retention rates successfully.

According to Jenicke, Kumar and Holmes (2008, 461), portions and not necessarily the entire Six Sigma methodology can be used to improve many processes within a university at any level of governance. Institutions can identify projects, set goals and establish appropriate measurements. These projects may be, *inter alia* in the academic and academic support area, institutional services, financial support and services, human resources, registrations and residences. The basic difference between TQM and Six Sigma concepts is the approach; TQM focuses on conformance to requirements and a strategic approach to maintain existing quality standards; whereas, Six Sigma has continuous improvement by restricting the number of defects at its centre. The implementation of Lean Six Sigma will help an institution to identify the processes that should be enhanced and promises to help an institution to determine which processes and activities add value and which do not. It will eliminate waste or non-value added activities.

CONCLUSION

This article reflects on the integration of Six Sigma and Lean Six Sigma with TQM methodologies in higher education. It investigates the implementation of its methodologies to enhance processes, reduce waste and increase satisfaction and profit within the higher education environment. The value of TQM and its integration with Six Sigma and Lean Six Sigma is that it offers structured methodologies in order to ensure continuous improvement, the reduction of waste and cost and the achievement of customer satisfaction. The integration of Six Sigma and Lean Six Sigma with TQM in the higher education sector might revitalise its speculated faded missionary appeal. It requires effective planning, an integrated strategy and a top-down approach where senior management demonstrates their commitment to the notion of continuous improvement and waste reduction.

REFERENCES

Allen, R. S. and R. H. Kilmann. 2001. The role of the reward system for a total quality management based strategy. *Journal of Organizational Change Management* 14(2): 110–131.

Anyamele, S. C. 2005. Implementing quality management in the university: The role of leadership in Finnish universities. *Higher Education in Europe* 30(3): 357–369.

Antony, J., N. Krishan, D. Cullen and N. Kumar. 2012. Lean Six Sigma for higher education institutions: challenges, barriers, success factors, tools/techniques. *International Journal of Productivity and Performance Management* 61(8): 940–948.

Bandyopadhyay, J. K. and R. Lichtman. 2007. Six Sigma approach to quality and productivity improvement in institutions of higher education in the United States. *International Journal of Management* 24(4).

Brits, H. J. 2010. A model for the integration of quality management, planning and resource allocation at institutions of higher learning in South Africa. Ph.D. thesis, North-West University.

Cheng, J. 2009. Six Sigma and TQM in Taiwan: An empirical study of discriminate analysis. *Total Quality Management and Business Excellence* 20(3): 311–326.

Cruickshank, M. 2003. Total quality management in the higher education sector: A literature review from an international and Australian perspective. *TQM & Business Excellence* 14(10): 1159–1167.

Deming, W. E. 1993. *The new economics: For industry, government, education*. Cambridge: MIT Press.

Drake, D., J. S. Sutterfield and C. Ngassam. 2008. The revolution of Six Sigma: An analysis of its theory and application. *Academy of Information and Management Sciences Journal* 11(1): 29–44.

Easton, G. S. and S. L. Jarrell. 1998. The effects of total quality management on corporate performance: An empirical investigation. *Journal of Business* 71(2): 253–307.

Essop, A. 2016. Fees must fall – but not at the expense of quality higher education. *The Conversation*. http://theconversation.com/fees-must-fall-but-not-at-the-expense-of-quality-higher-education-62520 (Accessed 11 March 2017).

Foster, S. T. 2007. *Managing quality: Integrating the supply chain.* Upper Saddle, NJ: Pearson Education International.

Goffnett, S. P. 2004. Understanding Six Sigma: Implications for industry and education. *Journal of Industrial Technology* 20(4): 2.

Hargrove, S. K. and L. Burge. 2002. Developing a Six Sigma methodology for improving retention in Engineering Education. Paper delivered at 32nd ASEE/IEEE Frontiers in Education Conference, 6–9 November 2002, Boston.

Higgs, P. and J. Smith. 2006. *Rethinking truth.* Cape Town: Juta.

Jenicke, L. O., A. Kumar and M. C. Holmes. 2008. A framework for applying Six Sigma improvement methodology in an academic environment. *The TQM Journal* 20(5): 453–462.

Kiley, K. 2011. Inside higher education. Where universities can be cut. http://www.insidehighered.com/print/news/2011/09/16unc (Accessed 28 August 2013).

Koch, J. V. 2003. TQM: Why is its impact in higher education so small? *The TQM Magazine* 15(5): 325–333.

Kwak, Y. H. and F. T. Anbari. 2004. Benefits, obstacles and future of six sigma. *Technovation: The International Journal of Technological Innovation, Entrepreneurship and Technology Management* 26(5/6): 708–715.

Liston, C. 1999. *Managing quality and standards*. Buckingham: Open University Press.

Loder, C. P. J. (Ed.). 1990. *Quality assurance and accountability in higher education.* London: Kogan Page.

Maguad, B. A. 2007. *Lean strategies for education: Overcoming the waste factor. Education* 128(2): 248–255.

Mazumder, Q. H. 2014. *Applying Six Sigma in Higher Education quality improvement*. 21st ASEE Annual Conference and Exposition. 15–18 June 2014, Indianopolis.

Meirovich, G. and E. J. Romar. 2006. The difficulty in implementing TQM in higher education instruction. *Quality Assurance in Education* 14(4): 324–337.

Mehrotra, D. 2010. Applying total quality management in academics. http://www.isixsigma.com/library/content/c020626a.asp/action=print (Accessed 2 January 2015).

Motwani, J. and A. Kumar. 1997. The need for implementing total quality management in education. *International Journal of Educational Management* 11(3): 131–135.

Oakland, J. S. 1998. *Total quality management.* Oxford: Butterworth Heinemann.

Pryor, M. G., C. Alexander, S. Taneja, S. Tirumalasetty and D. Chadalavada. 2008. The application of Six Sigma methodologies to university processes: The use of student teams. *Journal of Case Studies in Accreditation and Assessment* 2: 123–136.

Raifsnider, R. and D. Kurt. 2004. *Lean Six Sigma in higher education: Applying proven methodologies to improve quality, remove waste and quantify opportunities in colleges and universities*. White Paper: Xerox Corporation.

Revere, L. and K. Black. 2003. Integrating Six Sigma with Total Quality Management: A case example for measuring medication errors. *Journal of Healthcare Management* 48(6): 377–391.

Rust, R. T., C. Moorman and P. R. Dickson. 2002. Getting return on quality: Revenue expansion, cost reduction, or both? *Journal of Marketing* 66: 7–24.

Saunders, I. W. and M. Walker. 1991. TQM in tertiary education. *The International Journal of Quality & Reliability Management* 8: 91–103.

Shah, A. 2009. The impact of quality on satisfaction, revenue, and cost as perceived by providers of higher education. *Journal of Marketing for Higher Education* 19(2): 125–141.

Simons, N. 2013. The business for Lean Sigma in Higher Education. *ASQ Higher Education Brief* 6(3). http://asq.qic/display-item/index.html?item=35964 (Accessed 12 April 2017).

Taitkonda, L. 2007. Applying lean principles to design, teach and assess courses. *Management Accounting Quarterly* 8(3): 27–28.

Van Vught, F. 1996. The Humboldtian university under pressure: New forms of quality review in western European higher education. In *Inside academia – new challenges for the academic profession*, ed. P. A. M. Maassen and F. Van Vught, 163–140. Utrecht: Cheps.

Vroeijenstijn, A. I. 1995. *Improvement and accountability: Navigating between Scylla and Charybdis*. London: Jessica Kingsley.

Willis, T. H. and A. J. Taylor. 1999. Total quality management and employers' perspective. *Total Quality Management* 10(7): 997–1007.

Youssef, M. A., P. Libby, A. Al-Khafaji and G. Sawyer. 1998. TQM implementation in academe: A framework for further investigation. *International Journal of Technology Management* 16: 584–593.