

Developing organisational learning through QC story

Ronildo Souza^a, Sérgio Sousa ^{b*} and Eusébio Nunes^b

^a*Production and Systems Department, University of Minho, Braga, Portugal;* ^b*ALGORITMI Research Centre, University of Minho – DPS, Braga, Portugal*

Continuous improvement or more generally improvement is a necessity for companies in a dynamic context. The effectiveness and efficiency of such improvement can foster company sustainability, particularly if it exhibits characteristics of a learning organisation. This paper shows a methodology to develop organisational learning through the use of one quality improvement methodology known as Quality Control (QC) Story. The work is based on a case study from a manufacturer of electronic products. It describes QC Story application over 10 years and its effects on key performance indicators. Organisational learning is assessed through a questionnaire survey. A method to manage knowledge based on a lessons-learned procedure is described and a generalisation is induced. Results suggest that repetitive use of QC story along with the presented procedure of lessons-learned contributes to improving processes performance over long periods. It is also concluded that this company using the presented procedure exhibit characteristics of a learning organisation.

Keywords: electronic products; knowledge management; manufacturing; organisational learning; performance management; quality control story; quality improvement

1. Introduction

For industries, the market has become increasingly competitive, uncertain, and dynamic in terms of products, technology, requirements, personal skills, etc. Facing this context, companies introduce transformations in business models to improve its ability to produce quality products and services for its customers (Lam, Lee, Ooi, & Lin, 2011). Companies that aim to remain and grow in competitive markets are opting increasingly to reduce their production costs, launch new products, looking for new markets for their products, etc. This can be achieved, among other ways, by the continuous improvement of its processes and products.

Continuous improvement of processes is a key concept of Total Quality Management (TQM) (Chen, Lu, Wang, Jang, & Dahlgaard, 2015), but it is not the only way of improving a process. For example, improvement projects such as Six-Sigma (Lopes, Nunes, Sousa, & Esteves, 2011; Antunes, Sousa, & Nunes, 2013) can result in significant discontinuous improvement. Other methodologies such as re-engineering or automation can also result in improved performance.

In the early 1980s, the learning organisation (LO) concept was expressed and implemented by academics and practitioners as a way to maintain continuous improvement, having gained wide acceptance along of companies (Hill, 1996). LO encourages individuals to be creative in their thinking and invite them to continuously increase their competency to produce desired results (Sohal & Morrison, 1995). Organisations have been finding ways to encourage a learning culture so that employees can also contribute towards decision-

*Corresponding author. Email: sds@dps.uminho.pt

making and change implementation and this kind of culture can be cultivated through the execution of TQM practices (Choi, Kim, & Yoo, 2016). Lee, Ooi, Sohal, and Chong (2012) investigated the linkage between TQM practices and LO in 206 Malaysian manufacturing organisations that have been ISO 9000 certified. The findings indicate that four TQM practices (process management, human resource focus, leadership and information, and analysis) are positively related to LO, whereas strategic planning and customer focus have no significant relationships with LO.

More recently the so-called New Industrial Revolution – Industry 4.0 can introduce new production paradigms with high-performance gains. In fact, performance improvement can have many connotations but typically means to improve yield, to increase the profitability of capital invested, to reduce defective units. Many of these goals can be associated (and monitored) through key performance indicators (Sousa, Aspinwall, & Guimarães Rodrigues, 2006).

Considering different methodologies for improvement along with evolutions of information systems and automated data acquisition systems (Guerra, Sousa, & Nunes, 2016), the relevance of continuous improvement may be questioned. Yunus, Alsoufi, and Irfan (2016) argue that these methodologies may increase the application of basic quality control tools, however, the new revision of ISO 9001:2015 replaces the term ‘continuous improvement’ by ‘improvement’, suggesting that other types of ‘discontinuous’ improvement may be used to improve systems effectiveness in achieving customers’ requirements and improving efficiency resulting in a competitive company.

Other mechanisms to improve company competitiveness may compete for internal resources. For example, to increase market share companies can develop new products and the investment in innovative processes and products can also contribute to company competitiveness. This can be considered a ‘discontinuous improvement’. Considering that exists a variety of alternatives to improve company performance, and every company operates in a different environment with different resources and strengths (Wu & Chen, 2004), there is not a clear methodology that, in a given context, indicates what method for improvement should be adopted. To contribute to such discussion, the activities associated with each methodology and the results achieved can be useful information to decide the adoption of a given methodology.

In many manufacturing processes, there is a learning curve, which means that over time the performance in terms of productivity and quality improves (Yang & Rhee, 2017). When a new product starts production (not necessarily bigger, more complex and with more demanding specifications), the process performance may reduce. So, it can be concluded that over bigger periods of time the changes in the shop floor, particularly the introduction of new products, may cause a decrease in quality/productivity performance. So it can be argued that there is a need for studies to ascertain the contribution of improvement methodologies in dynamic and complex environments.

In quality control and improvement activities, people should collect data, analyse it for valid information, disseminate it, generate knowledge about possible solutions, transfer that knowledge to other employees, and make it available for reuse. As the steps follow and the application of an improvement method is repeated, individual knowledge is expanded and can reach the organisational level. For example, QC story or Plan-Do-Check-Act (PDCA) can structure such activities. It can be argued that by making this dynamic possible, QC story allows people to balance cognition with behaviour (Versiani, Oribe, & Rezende, 2013). According to quantitative research carried out by these authors, from a theoretical point of view, this methodology contributes to four dimensions of organisational learning (Templeton, Lewis, & Snyder, 2002): knowledge acquisition, distribution, information

interpretation and organisational memory. This also confirms Senge's (2014) assumption that organisations committed to quality management are uniquely prepared to become LO. However, few companies have achieved this ideal, because managers do not know the precise steps for building an LO (Garvin, Edmondson, & Gino, 2008). Thus, there is an opportunity to provide more empiric data to support or reject Templeton et al. (2002) conclusions and simultaneously show how it can be achieved.

The main objective of this work is to present how can continuous improvement be successfully applied and contribute to an LO. To that end, a case study using continuous improvement, particularly QC story (Sugiura & Yamada, 1995) in an LCD and LED TV production industry, in Brazil, is presented. This work analyses activities and results over 10 years on the use of such methodology and its impact on performance (productivity and quality) and organisational learning (OL). The specific objectives are: to describe how QC story can be systematically used as a tool to analyse and solve the main problems that affect the productive process and investigate its causes; to analyse the impacts (short-term quantitative results and long-term effects), to synthesise a method that by using QC story contributes to a learning organisation.

This paper is organised as follows: Section 2 presents a literature review on QC Story and knowledge management during which four research questions are formulated. Section 3 presents the research methodology, involving a case study and a survey. Section 4 presents the use of QC story in a multinational company (including key activities, quantitative results, and relevant context). In Section 5, the management of knowledge in the context of QC story is presented and assessed through a survey based on a questionnaire. Section 6 makes a synthesis of the requirements and initiatives that through QC story develops OL. The paper ends with conclusions, limitations and future work.

2. Literature review

2.1. Problem-solving and process improvement

There are two types of process improvement: (i) systematic problem solving and (ii) improvement projects. The difference between these two types occurs from the identification of the need for improvement. Improvement projects are linked to strategic objectives of the company (clients, competitors, etc.) and problem-solving refers to a set of activities that will be executed in a reactive or preventive way to a problem. As shown in Section 2.2, QC story is more suitable to address systematic problem-solving.

A problem is an undesirable result of a process. Commonly, people believe that they can solve any type of problem-based on their experience; however, facts and data are the only criteria of true knowledge (Campos, 1992). For this reason, the analysis of the process is important to solve problems.

There are a variety of tools for use in problem-solving, each with its specific characteristics, degree of complexity and application (Tague, 2005). They can be used separately, but also grouped together to solve problems of different levels of complexity. For Hosotani (1992), the functions of the tools are: discovering problems, organising information, generating ideas, analysing causes, taking action, making improvements and establishing control. Table 1 presents quality tools that are more appropriate to use in stages of the QC story (JUSE, 1991).

2.2. Quality control story

QC story is known as a standardised approach to problem-solving and standardisation, or PDCA (Kondo, 1990). QC story is widely thought in Brazilian Universities (known as

Table 1. QC story tools by stage.

		Stages of QC story							
	Quality tool	1 – Problem identification	2 – Observation	3 – Analysis	4 – Action plan	5 – Action	6 – Check	7 – Standardisation	8 – Conclusion
Seven quality	Cause and Effect Diagram			✓			✓		
	Pareto diagram	✓		✓			✓	✓	✓
	Check Sheet	✓	✓	✓			✓		✓
	Histogram			✓			✓		
	Scatter diagram			✓			✓		
	Control Charts			✓		✓	✓	✓	
	Graphics	✓		✓			✓	✓	✓
Other Tools	FMEA	✓		✓	✓		✓		
	Sampling inspection		✓	✓			✓		
	Quality Charts	✓	✓	✓	✓		✓		✓
	Operational Research		✓	✓	✓				
	Brainstorming	✓		✓	✓				✓
	Five Whys			✓					
	Flowchart		✓		✓				✓
	Gantt Chart		✓		✓				✓
	GUT Matrix	✓							
	5W2H		✓		✓				

Source: adapted from JUSE (1991).

MASP) and is a popular method for quality improvement (Campos, 1992). This method consists of a set of eight stages to be carried out sequentially (Table 2). There are small variations of this method, for example, Kondo (1990) includes stage three and four as one stage, resulting in a total of seven stages. QC Story will provide a means of assisting managers to address important aspects of the organisation's day-to-day life, such as (Rossato, 1996):

- Analyse and prioritise problems;
- Establish control in certain situations;
- Divide the problem into parts that will be analysed, according to a logical process;
- Definition of more likely causes for the problem;
- Take corrective action to minimise or eliminate the effects of the problem;
- Continuous process improvement.

The application of QC story should result in problem-solving and process improvement, however, many process improvements fail to meet expectations (Hicks & Matthews, 2010). Furthermore, after obtaining positive results, a new challenge arises to keep the achieved level of performance over time (Wu & Chen, 2004), because most improvement programmes end in failure (Keating, Oliva, Repenning, Rockart, & Sterman, 1999). Thus, individual case studies that present positive results of process improvement should be re-assessed after a period of time (weeks, months or years) to ascertain whether the improved level of performance is being maintained. The relevance of QC story depends on its ability to achieve efficiency improvement, not only after the project ends but also its results should be maintained over time. At this moment a pertinent question can be asked: Can QC story be used to continuously improve the performance of a company?

The continuous improvement has been considered as an important ally of organisations to overcome their challenges resulting from changes in the internal environment or external environment, such as new technologies, shifting customer needs (Pantouvakis & Bouranta, 2017) or new products/services, new employees new laws ... In this dynamic environment, companies can do different things to achieve and maintain competitiveness. This can happen through product design, new production processes, differentiated marketing approach or even new ways of conducting training (Porter, 1990). In this way, organisations are able to adjust to the competitive environment, with technology and resources they have to overcome their competitors, gain markets and, consequently, achieve desired results.

Table 2. QC story stages.

PDCA	Stage	Objective
P	1 – Problem identification	Define the problem and its importance.
P	2 – Observation	Investigate the specific characteristics of the problem with a broad view and from different points of view.
P	3 – Analysis	Discover the root causes.
P	4 – Action plan	Design a plan to block root causes.
D	5 – Action	Block the root causes.
C	6 – Check	Verify that the lock was effective.
A	7 – Standardisation	Preventing recurrence of the problem.
A	8 – Conclusion	Review the entire QC story trajectory. Record and apply the lessons-learned.

However, this change not only provides improvement opportunities but also threats (Pantouvakis & Bouranta, 2017).

Organisations need to develop their own appropriate improvement method (Chien, Lin, & Ya-Hui Lien, 2015). According to Despeisse, Mbaye, Ball, and Levers (2012), the information on how these improvements are achieved is sparse. Chien et al. (2015) concluded that continuous improvement has no impact on developing radical innovations, but is the best a method to get incremental innovations. One can suggest that QC story can be effective to provide performance improvement in dynamic environments. The following hypothesis can be made:

H1: QC Story contributes to, in dynamic environments, generate quality improvement over long periods (>5 years).

Considering this hypothesis, QC Story usage could be the basis of an organisational learning culture, as it will be discussed in the next section.

2.3. Organisational learning

Organisational learning (OL) is considered a condition for organisations to develop and survive in a competitive environment (Fiol & Lyles, 1985), because in contexts requiring a fast pace of innovation, the capacity to undertake change is an essential requirement for the development of new products and services that continuously satisfy markets and customers.

Although there is a consensus that OL is a necessary foundation for organisational change and competitiveness (Dodgson, 1993), the question of how to promote learning is still not sufficiently addressed (Garvin et al., 2008; Despeisse et al., 2012; Wang & Wang, 2016; Pantouvakis & Bouranta, 2017). As the organisation is an inanimate entity, it is the people who learn, therefore, organisations that are effective in the learning process balance individual and collective practices, both formal and informal, to develop their competitive advantage. One of these formal practices has been the systematic solution of problems, whose main approach in Brazil is done by the QC Story application (Campos, 1992). This method seems to favour different types of learning (Garvin, 1993). Whenever a new problem arises, and it is solved and the organisation adjusts its way of working to avoid recurrence, this provides, incrementally, a new source of knowledge and improvement. However, knowledge is intangible, context-specific, relational, dynamic and difficult to grasp (Wang & Wang, 2016). Thus, the following hypothesis can be made:

H2: Knowledge can be obtained from the activities that constitute QC Story.

Some authors use the term LO as a broader term than OL. In the view of Senge (1990, 2006, 2014), the learning disciplines that are the core of an LO are: (i) personal mastery; (ii) mental models; (iii) shared vision; (iv) team learning, and (v) systems thinking. Garvin (1993) considers that an LO must master five activities: (i) solving problems systematically; (ii) experimenting with new approaches to work; (iii) learning from past experience; (iv) learning from other companies and from customers; and (v) transferring knowledge throughout your organisation. Later, Garvin et al. (2008) suggested that creating an LO requires three building blocks: (i) a supportive environment; (ii) concrete learning processes; and (iii) leadership that reinforce learning. Thus, it can be concluded that despite the inexistence of a single framework that companies may adopt to manage knowledge to become an LO, different authors propose similar requirements (Chang & Sun, 2007). However, there are no exact requirement specifications about its inputs, processes, and outputs (Lin, 2013) and its implementation is difficult and risky (Wang & Wang, 2016).

Finally, the information on how to develop knowledge management systems (KMS) is scarce (Despeisse et al., 2012). The following hypothesis can be made:

H3: A system can be developed based on outputs from QC story usage to perform knowledge storage, retrieval, and transfer.

QC story is not always capable of developing OL, i.e. to apply knowledge to efficiently solve new problems.

Templeton et al (2002) developed a questionnaire based on four constructs that can assess the level of OL:

- (1) Knowledge acquisition – the organisation's ability to absorb new knowledge through problem-solving.
- (2) Information distribution – degree of availability of information to members of the organisation.
- (3) Information interpretation – ability to explore new ideas and interpretations of problems encountered and change them whenever necessary.
- (4) Organisational Memory – The strength and intensity of the organisation is that its members can pass on their knowledge in the form of lessons-learned and written documents.

According to Tucker, Edmondson, and Spear (2002), three factors may impede learning at the organisational level: (i) the heroic attitude of employees; (ii) the structural constraints of the function, such as lack of adequate time and means and; (iii) the low-status position of frontline employees *vis-à-vis* specialists and managers. For Argyris (1977), learning difficulties at the organisational level occur due to human games and organisational norms that inhibit people from any action that confront company policies and objectives. Such a situation leads to the establishment of a generalised habit of camouflaging problems that, over time, inhibits people's ability to see errors. Given these findings, it can be concluded that OL is not a direct consequence of problem solving, but an effect that can be achieved if certain conditions are met. Furthermore, the company ability to adapt to dynamic environments relies on people's thoughts and behaviour and on organisational culture and management teams (Yang, 2015). Thus, the way in which the method is carried out and the context of its application can lead to different types and degrees of learning and the following hypothesis can be made:

H4: QC story team members have the potential to apply knowledge to efficiently solve new problems.

3. Research Methodology

A combined analysis involving both quantitative and qualitative approaches was defined. The research methodology uses a case study describing how a manufacturer of electronic products used QC story for problem-solving and to develop OL. Additionally, a questionnaire was developed and applied to all members participating in QC story to ascertain the perception of OL. The case study and the questionnaire provide multiple sources of evidence avoiding common method bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

3.1 Case study

The case study approach, applied in this work, has been used by several authors (Silvestro & Westley, 2002; Nagaraj & Selladurai, 2003), when attempting to understand complex

organisational problems, such as QC story long-term performance and its effects on OL. ‘It is the method of choice when the phenomenon under study is not readily distinguishable from its context’ (Yin, 2003, p. 3). Furthermore, to fully understand the motives, problems, and implications associated with continuous improvement, an in-depth knowledge of the organisations would be required.

There are different types of case studies (Yin, 2003). The explanatory kind seemed appropriate for the present research, as they seek to explain how and why some events occurred. This method benefits from the prior existence of several complex and rival theories. Explanatory theories can facilitate theory testing with a rich and extensive data collection effort, including qualitative and quantitative evidence.

The choice between single-case and multiple-case studies depends on the research objectives and the availability of resources. Conducting multiple-case studies is described as being similar to replication of experience. In deductive methods the debate is centred on sample size, however, in inductive research, the reliability issue depends more on multiple sources of data (McAdam & Lafferty, 2004). In this research, a convenient sample is selected based on location and data accessibility. The general requirements of using a quality improvement methodology and developing activities towards OL were verified in the selected company. Therefore, in this research, an explanatory single-case study was performed.

The case study protocol must assure that data collection would involve converging lines of inquiry and triangulation of evidence. Within each data source, there is an emphasis on depth and quality, rather than population size. Finally, there have been repeated calls for more qualitative case study-based research in operations management (Silvestro & Westley, 2002), despite the clear difficulty of drawing generalised conclusions from a small number of instances.

The unit of analysis is associated with the kind of case to which the phenomena under study and the research problem refer, and about which data are collected and analysed (Hussey & Hussey, 1997). It should contribute to clarify the boundaries and scope of the study. In this research, the unit of analysis is the QC story team, its activities and its associated environment (performance indicators of manufacturing lines).

The case study describes the activities adopted by the company over a decade (between 2007 and 2016) and its sequence (Figure 1).

QC story consists of stages four and five of Figure 1. In that view, stages one to three allows preparing QC story application. This sequence starts by studying the production flow of new products, because it has the potential of bringing new problems/defects, and identifies areas (processes or product) for improvement. If there are new employees requiring training, or new quality tools are needed in problem-solving, training is provided to employees. After repeatedly applying the above stages, the case study shows quantitative evidence of company’s performance. This will provide evidence to support or refute *H1* and *H4*. This quantitative data obtained through direct observation and records allows overcoming limitations of works that make conclusions based on subjective perceptions and do not evidence any actual objective material, such as in Chien et al. (2015).

The studied company developed a procedure to manage organisational knowledge, which involves a set of processes whose objective is to support the creation, capture, storage, dissemination, and use of experiences and lessons-learned within organisations, that arises from using QC story. This procedure is described. Data on its development and use will contribute to support or refute *H2* and *H3*.

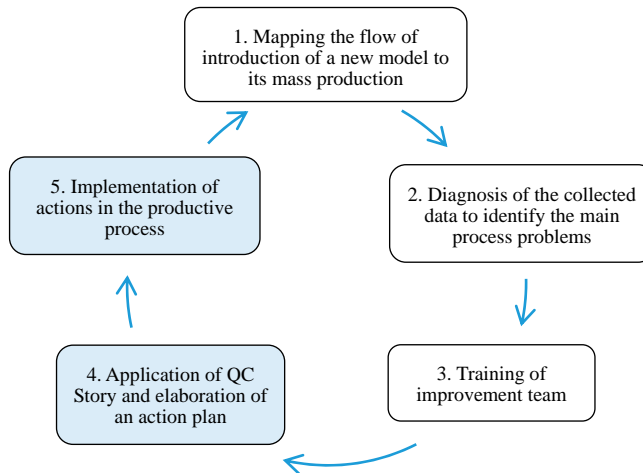


Figure 1. Sequence of activities adopted.

3.2 Questionnaire

A research instrument in the form of a questionnaire was developed and applied to all 26 participants (managers, engineers, analysts, and technicians) in the improvement groups using QC Story and contributing to the *lessons-learned* procedure.

The aim of this questionnaire is to measure the degree of agreement of the participating members on systematic problem-solving activities using QC Story and, consequently, to measure the extent to which they contribute to OL. Each of the questions contains a 10-point Likert scale for marking, by the respondent, their degree of agreement. If overall agreement among respondents is high, one can conclude that QC Story significantly contributes to OL. On the other hand, if this agreement is low, QC Story contributes little to OL, even if it is well applied and problems are solved effectively. The used questionnaire assesses the level of OL based on four constructs proposed by Templeton et al. (2002): knowledge acquisition (7 questions), information distribution (5 questions), information interpretation (5 questions) and organisational memory (3 questions). The questionnaire is based on the 31 questions proposed by Templeton et al. (2002) and was adapted by Versiani et al. (2013). These steps allow us to conclude that the instrument has content validity (Sousa, Aspinwall, Sampaio, & Rodrigues, 2005). The 20 survey questions are presented in the [appendix](#).

To further validate the survey instrument, questionnaire reliability and construct validity was analysed.

The convergent validity was assessed using *IBM® SPSS® Statistics version 24*. Convergent validity can be tested by calculating composite reliability (CR), Cronbach's alpha, and the average variance extracted (AVE) of each construct (Gefen, Straub, & Boudreau, 2000). Cronbach's alpha represents the ratio between the true and the observed variance; values greater than 0.7 denote homogeneity of data and good scaling of the instrument (Pantouvakis & Bouranta, 2017) (Cho, Kim, Park, & Cho, 2013). When the AVE by each factor exceeds the proposed cut-off value of 0.5 also indicates the convergent validity of the instrument, and thus the scales are judged to be reliable.

The Kaiser-Meyer-Olkin (KMO) test is used to show if the sample size is appropriate to do factor analysis. This test shows the proportion of the variance that the variables as a whole have in common or the proportion of this that are due to common factors. The

KMO has normalised values between 0 and 1. A KMO value below 0.5 indicates that the dataset is not indicated to use the technique, and KMO values closer to 1 indicate data adequacy.

The results of the survey based on the questionnaire will support or refute *H2*, *H3*, and *H4*.

Data were analysed. Descriptive statistics of the variables were calculated: the arithmetic mean as a measure of central tendency since it represents the data well and has the advantage of being a measure that takes into account all values. To measure variability of data, standard deviation was calculated. The number of valid observations was also recorded and null and unanswered questions were left blank.

4. Company background and the use of QC story

4.1. Company background

This section presents the company and, in particular, the new products introduction process and mass production, addressing in particular TVs and Monitors. It also describes the application of the problem-solving methodology and its results.

The company Envision Ind. Eletronica, where the study was carried out, is classified as a large company (annual turnover = 2.5 Billion R\$ and approximately 1200 employees) in the electro-electronic segment and belongs to a multinational group with its origins and headquarters in China. Its production is characterised as an intermittent process since its volume is determined by variable customer demand.

The company receives from customers (other companies) product specifications to mass-produce new products. The Research and Development (R&D) Department, with the support of other departments develops the necessary activities to plan for its mass production. This process involves many activities. The existence of a New Product Introduction (NPI) plan is the basis for the successful launch of a product. The NPI consists of the following activities:

- (a) Receiving and studying product specifications;
- (b) Requesting material for development;
- (c) Receiving materials such as plates, test equipment, and samples;
- (d) Developing production plans, modifications, and improvements;
- (e) Testing pilot plates and products;
- (f) Deploying continuous process improvements;
- (g) Evaluating functional performance of the product in the field; and
- (h) Analysing and applying product/process improvements.

Once the activities (a) to (e) are concluded an evaluation is made to decide whether the process is ready for mass production. If it is not ready, further repetitions of those activities are done until an acceptable production plan is achieved. After stage (e), internally called *release phase*, the new product is ready to be mass-produced. The remaining activities are also from the responsibility of R&D Department and are done after the beginning of mass production.

Once the peaks of problems that are common in the *release phase* of the new product are overcome, the same, albeit to a lesser extent, may present some repetitive defects throughout its production process. This is mainly due to possible changes in the workforce, material quality, machine breakdown, engineering changes, and operational failures, among others. When this occurs, the company needs to act cooperatively, using QC story to find solutions.

4.2. QC story

At some point, after the start of mass production of a new product, the situation was critical because of the daily defect rate, which should be below 2.8%, reached 7.8%, with peaks exceeding 10%. This was happening on a series of recently released LCD monitors to be mass-produced.

Initially, an improvement team was formed, consisting of five representatives from several departments: Production, Quality, and Engineering, which would solve the problems of product quality. The definition of the teams and the responsibility for each member was based on knowledge, experience, and their indication by the manager of each department took into consideration the degree of motivation and commitment. Usually, each QC story team, formed to solve a specific problem, was constituted by four or five elements.

This company started using QC story in 2007 and, during a decade, approximately 30 new members entered that team. During that period six members left the company. By the end of 2016, the QC story team had 26 elements from the following departments: Quality (6 members); R&D (7 members); Engineering (8 members); Manufacturing (2 members); Electrical processes (2 members); and Materials (1 member).

The application of the QC story started in January 2007 with the problem identification and it was verified that 4.2% of defective units were caused by a single component. After following all the steps presented in Table 2, the new level of defective components was under 0.2%. Details of this improvement are described in Silva (2016).

In the following months, it was possible to observe a considerable evolution of quality and reduction of defect indices. Analyses and solutions in the form of reports, collected between January and July 2007, were appended in Figure 2, evidencing the five improvement actions and their effectiveness.

Overall, after the first six months of using the QC story, five improvement projects were carried out, which resulted in a product defects level of 3.7% in the final of this period (about half of the initial). The main technical improvements that were implemented during this period were:

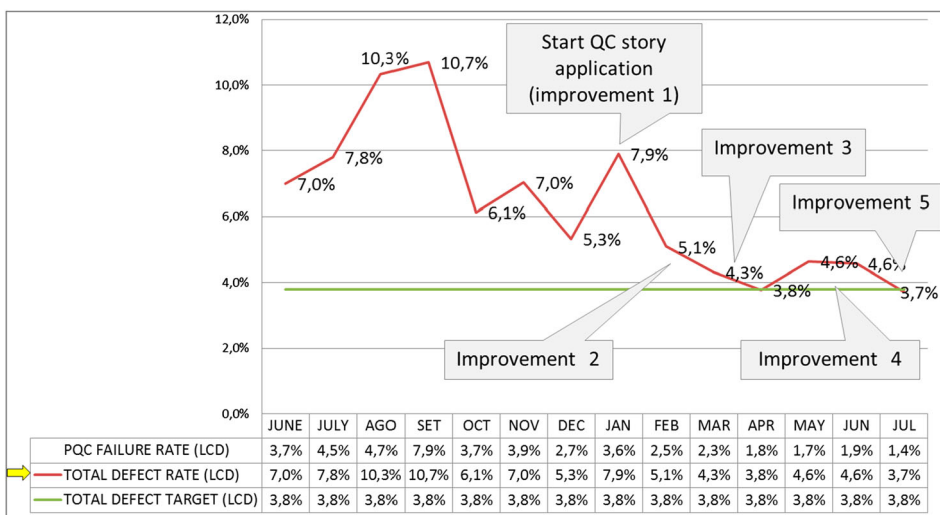


Figure 2. Chart of total defect rate evolution (data from June 2006 to July 2007).

- (1) Checking adequacy of testing equipment and packaging to avoid damaging semiconductor components;
- (2) Operator training for the correct use of electrical functional test equipment;
- (3) Development of new connection terminals and insulation test equipment;
- (4) The Inclusion of on–off switches in all test equipment to avoid electrical over stress problems, which usually occur when connecting boards directly to energised equipment.
- (5) Application of data pre-set in white balance settings, in order to reduce the number of adjustment faults and rejection of products with parameters of brightness and colour outside the specified.

These activities developed in the company generated significant changes in the new product introduction (NPI) process and mass production. Taking into account the initial situation, the production team identified an evolution in the treatment of problems, such as the involvement of areas and departments, which began to act more quickly in the resolution of problems. This generated visual indicators that were no longer restricted to managers and started to be seen by all employees, through an updated, real-time electronic scoreboard, posted at the beginning of each production line, through a control system called *Shop Floor Integrated System (SFIS)* that includes traceability functionalities. Work instructions and procedures were also improved, as well as the implementation of a smarter quality policy, based on the practical knowledge of the employees and adapted to the demands of the main customers, such as Sony, Panasonic, Lenovo, and Dell.

From 2007 to 2016, the average number of defective products (YDR) reduced from 4.8% to 0.51% (Figure 3). Simultaneously, over this period the NPI (in the productive process) rose from about 17 new products per year (average in the first 4 years) to more than 43 new products per year (average in the last six years).

The key difficulties encountered in the application of QC story can be described as:

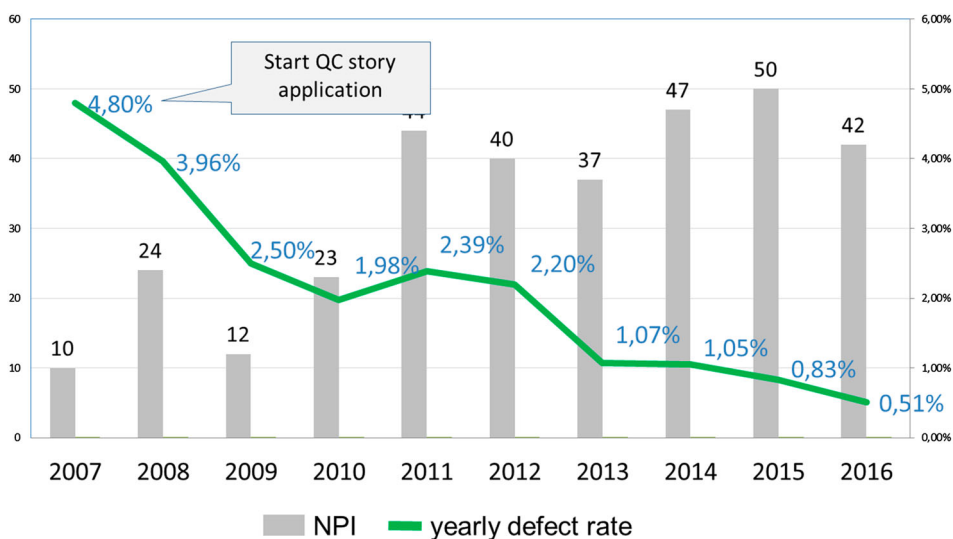


Figure 3. Total process quality performance.

- The company did not have a well-defined system of procedures in the plate test process;
- Company culture, initially focused on quantity, producing without much attention to quality, has generated difficulties in implementing the QC story methodology in its production process. However, in less than a year, this was overcome;
- Lack of training of improvement team members – in which only 84% of the group elements has mastery over QC story tools – is still a negative point that needs to be addressed;
- There was some initial resistance of employees during the establishment of an OL process due to poor understanding of its usefulness.

4.3. Discussion

Since the first report of the application of QC story, it has been shown to be important to analyse data from a problem, where it occurred, in order to create a judgment and an adequate action plan to solve problems. The application of QC story involved 26 employees and, over a period of 10 years, the organisation has never ceased to have problems, but gradually learned to reduce them in a systematic way. During this period the rate of NPI increased (for about 17 new products per year to more than 43 new products per year), but the quality indicators improved (from 4.8% of defective units to 0.51%). This increase in the number of new products to be mass-produced and the variation in the number of team members suggest an internal dynamic environment. During this period, particularly in this sector, the new products also had new requirements that posed new manufacturing challenges. The improvement of the key quality indicator (Figure 3) in this dynamic environment provides evidence to support *H1*.

Overall, the QC story brought greater involvement of employees and product quality improvement, especially in the release phase. QC story works by coping with problems and fosters individual learning from overcoming day-to-day problems, assuming that the best way to learn is by solving problems and that people need to be challenged periodically, it can be concluded that problems and challenges improve the performance of the mind. This type of learning might be effective as the case study suggests.

The evolution of indicators YDR and NPIR suggests that the company has an organisational profile that learns from its problems. These indicators provide evidence that learning is maintained and transmitted to new collaborators (and then it is applied in new situations), suggesting supporting *H4*. These results could be explained not only by the repeated application of QC story but also by the establishment of an organisational learning process.

To get further details of how the company achieved, maintained and improved this success, next sections will describe its OL process and will assess it through four constructs: knowledge acquisition, information distribution, information interpretation and organisational memory.

5. Organisational learning process

5.1. Development of an organisational learning process

The company has established the *Lessons-Learned Procedure*, with the objective that Quality, Production and Electrical and Mechanical Engineering departments register and share among them experiences obtained in complex problem-solving situations in the organisational environment. This procedure starts as the last stage of QC story application.

The procedure (see Figure 4) also requires that the record of these problems and their solutions be accompanied by recommendations for future projects in the form of reports

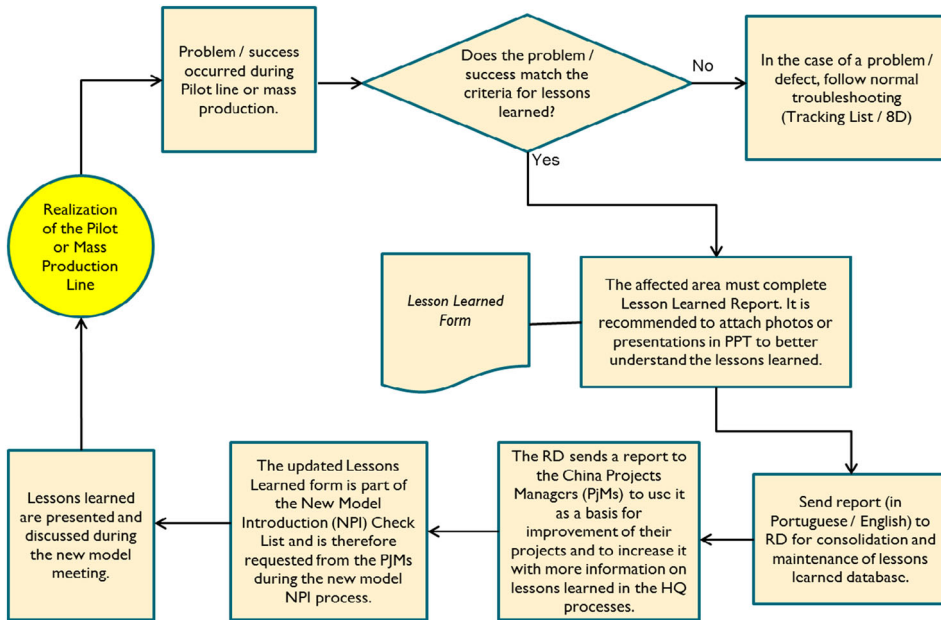


Figure 4. Lessons-learned procedure.

sent to R&D department. The R&D team consolidates lessons learned and forwards them to other group companies and/or to the Original Equipment Manufacturer (OEM) customer. This information is also addressed at the pilot line meeting (conducted prior to the introduction of a new product to be mass-produced) and closing meeting.

The *Lessons-learned Report* belongs to a set of documents that are used in the implementation of similar projects, promoting a continuous improvement cycle that is passed on to the new model's introduction process. In this way, a *lessons-learned* database is maintained and updated periodically. This database (with its relations represented in

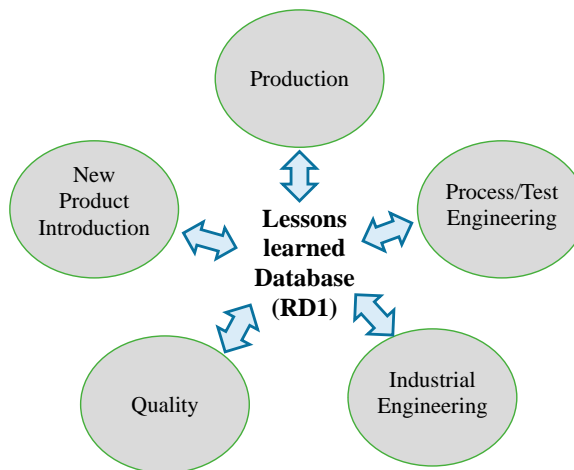


Figure 5. Lessons-learned database implementation.

Table 3. Criteria for elaborating the lessons-learned in each area.

Area	Criteria	Examples
Research and development	Larger defects that generate rework, Audit lockout points, Line stoppage, Safety or Design	Parts with plug-in or reliability problems: Bill of Materials, Engineering Change Notice errors, etc.
Quality (input inspection)	Larger defects that generate rework, Audit lockout points, Line stoppage, Safety or Design	Material problems, damaged parts from the supplier, etc.
Quality (Field defects)	Customer Complaint or field Rework	Epidemic problems, safety related failures, etc.
Production	Larger defects that generate rework, Line stoppage or Safety	Assembly error, etc.
Process engineering and testing	Larger defects that generate rework, Audit lockout points, Line stop, Safety or factory design modes	Manufacturing data error, calibration of equipment expired, failure to install safety equipment, etc.
Industrial engineering	Larger defects that generate rework, Audit lockout points, Line stop, Security, or factory design modes	Error preparing work instruction, non-application of an engineering change, etc.

Source: internal documentation.

Figure 5) is used as a reference for future improvements and accompanies the product throughout its mass production period.

Each department draws up its own criteria for drawing up the lessons-learned report, aware that they are the beneficiaries of the action. Thus, after several consensus meetings, it was defined that the criteria for elaborating the lessons-learned are described in Table 3. The establishment of criteria to create a *lesson-learn* based on QC story activities supports *H2*: Knowledge can be obtained from the activities that constitute QC Story.

The company developed a standard form to collect key information associated with the lessons-learned procedure. The purpose of standardising this is to make the database contains the essential information and are easy and fast to fill. The fields described in the form (Figure 6) have the following meaning:

- ID: sequential number of lessons-learned record;
- Date: day, month, year of occurrence;
- Phase: PP (Pilot Production) or MP (Mass Production);
- Activity: Workstation, event, task, etc.
- Problem/Success: Experience/fact that originated the lesson learned;
- Impact: effects (line stoppage, rework, percentage of defect, losses, etc.);
- Recommendation: suggestions for improvement, action to be taken, etc.;
- Image/attachment: photo or *PowerPoint*[®] presentation.

<div style="display: flex; justify-content: space-between; align-items: center;"> <div> <small>Monsen - Brasil</small> <small>R01/NP1</small> </div> <div style="text-align: center;"> </div> <div style="text-align: center;"> <small>TPV</small> <small>DO BRASIL</small> </div> <div> <small>FCB-71.103</small> </div> </div>									
RELATÓRIO DE LIÇÕES APRENDIDAS <i>LESSONS LEARNED REPORT</i>									
Nr ID	Data Date	PROJETO ou MODELO PROJECT or MODEL	FASE PHASE	ÁREA/DEPARTAMENTO AREA/DEPARTMENT	ATIVIDADE TASK	PROBLEMA/SUCESSO PROBLEM/SUCCESS	IMPACTO IMPACT	RECOMENDAÇÃO RECOMMENDATION	IMAGEM/ANEXO PICTURE/ATTACHED

Figure 6. Lessons-learned form.

Table 4. Constructs convergent validity.

Construct	AVE	Cronbach's α	CR	KMO	Eigenvalue
Knowledge acquisition	0.638	0.903	0.924	0.931	4.463
Information distribution	0.684	0.880	0.914	0.827	3.419
Information interpretation	0.641	0.857	0.899	0.658	3.207
Organisational memory	0.729	0.806	0.887	0.596	2.188

The developed lessons-learned procedure uses the output of each QC story to storage knowledge in a database. This database was used by the QC story team and is also available to other company members. The database development and use support *H3*: A system can be developed based on outputs from QC story usage to perform knowledge storage, retrieval, and transfer.

To provide further evidence to support or reject *H2*, *H3*, and *H4* the perception of staff involved in QC story was analysed through a questionnaire. According to Meredith, Raturi, Amoako-Gyampah, and Kaplan (1989), 'people's perceptions of reality' form appropriate data for operations management research. Nevertheless, the conventions of research triangulation were to see that the perceptions being documented were supported by evidence, rather than being purely subjective or personally held views.

5.2. Questionnaire results and discussion

This section reports the analysis of collected data in the research on organisational learning in the company. From the results of the questionnaire, its reliability and validity were assessed (Table 4).

KMO tests suggest sample size adequacy to perform factor analysis and from each construct, only one component was extracted (with an eigenvalue greater than 1). To assess the internal consistency for each construct, the Cronbach's alpha estimation and the item-to-total correlation were determined.

Because all Cronbach's α are greater than 0.7 and AVE is greater than 0.5 suggesting construct validity, the scales are considered reliable.

Figures 7 and 8 show the means and standard deviations of each of the 20 questions. In general, the agreement with the sentences was high. The mean ranged from 5.81 to 7.27, while the standard deviation ranged from 1.46 to 2.19.

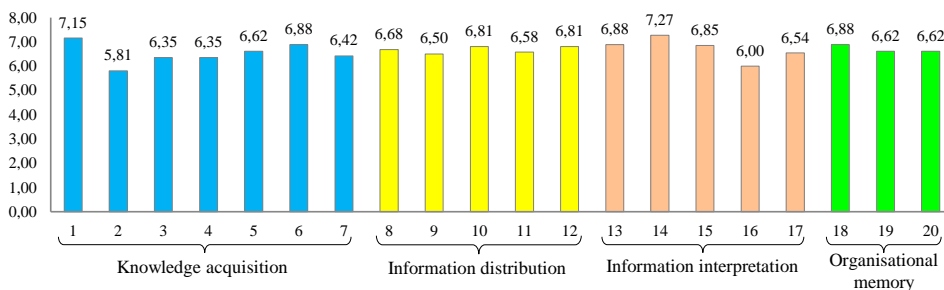


Figure 7. Average response for of each question organised by four constructs.

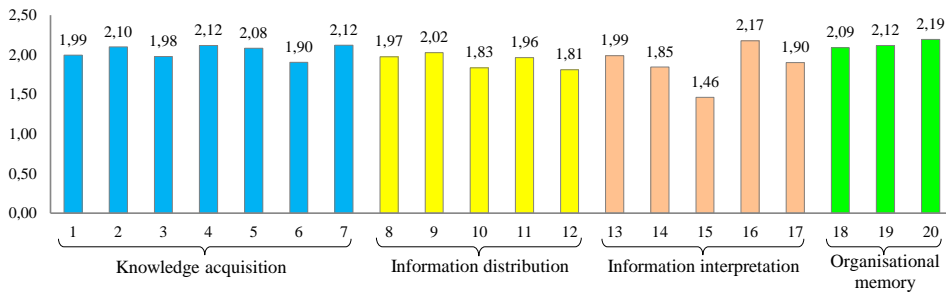


Figure 8. Standard deviation of each question organised by four constructs.

Discussion

As for the analysis of the standard deviations (Figure 8), the item with the lowest variation was the number 15 – ‘When they are faced with too much information, the groups manage to separate the necessary from the unnecessary ones’ – which indicates greater agreement about the focus on Information during a problem-solving process, which is a good feature of the QC Story application.

The item with greater variability, the number 20 – ‘The experience gained by members during the improvement project is passed on to people’ suggesting that the effect of the lessons-learned procedure on other departments was not assessed by some respondents.

The sentence with the higher result was number 14 – ‘The groups use quality tools (graphs, reports, plans, presentation models, software and other common forms of representation) to facilitate the interpretation of information’ – which demonstrated the high Frequency with which quality tools are used for the purpose of interpreting phenomena related to the causes and impacts of the solutions.

In turn, item 2, with the lower average, shows that the teams do not usually organise themselves into smaller groups, nor usually invite new participants or change their leadership. This means that improvement teams tend not to change their composition, thus avoiding engaging new members in the processes of problem analysis and problem-solving.

The overall perception of the constructs is:

- (1) Knowledge acquisition – the average value of this construct is greater than 6 suggesting that respondents agree that the organisation has the ability to absorb new knowledge through problem-solving (in this case QC story). This supports *H2*: Knowledge can be obtained from the activities that constitute QC Story.
- (2) Information distribution – the average value of this construct is greater than 6 suggesting that respondents agree that there is an availability of information to members of the organisation. This supports part of *H3*: A system can be developed based on outputs from QC story usage to perform knowledge transfer.
- (3) Information interpretation – the average value on this construct is greater than 6 suggesting that respondents agree that there is an environment that encourages the ability to explore new ideas and interpretations of problems encountered and change them whenever necessary. This supports *H4*: QC story team members have the potential to apply knowledge to efficiently solve new problems.
- (4) Organisational Memory – the average value of this construct is greater than 6 suggesting that respondents agree with the ability of its members to pass on their knowledge in the form of lessons-learned and written documents. The company

defined a lessons-learned procedure and implemented it. This supports part of *H3*: A system can be developed based on outputs from QC story usage to perform knowledge storage and retrieval.

The lessons-learned procedure elevates the organisation to a new level of learning because it creates an organisational memory capable of avoiding recurrences of problems already dealt with and solved. People who are experienced with these problems become more prepared to solve similar incidents and are also able to face new challenges. Through this procedure, productive support departments begin to create an organisational memory, so that this system, once applied and functioning regularly, elevates the company to a new level of knowledge management, an LO.

6. Synthesis of requirements and initiatives that through QC story develops organisational learning

This case study showed how the company successfully used QC story to improve performance. Despite the presented solution be specific to the studied company the overall process could be applicable to similar companies. A synthesis of the key activities is presented in Figure 9.

A quality improvement team is defined to follow up the introduction (to mass production) of new products. In the early stages of production, the majority of problems that were not anticipated by product design and process design are addressed with QC story. To participate in this quality improvement team new team members are trained on basic problem solving, mainly using basic quality tools. The diagnosis of collected data allows identifying problems (and successes) and implements effective corrective and/or preventive actions (knowledge acquisition). During this process, individual knowledge is immediately shared amongst team members (information distribution).

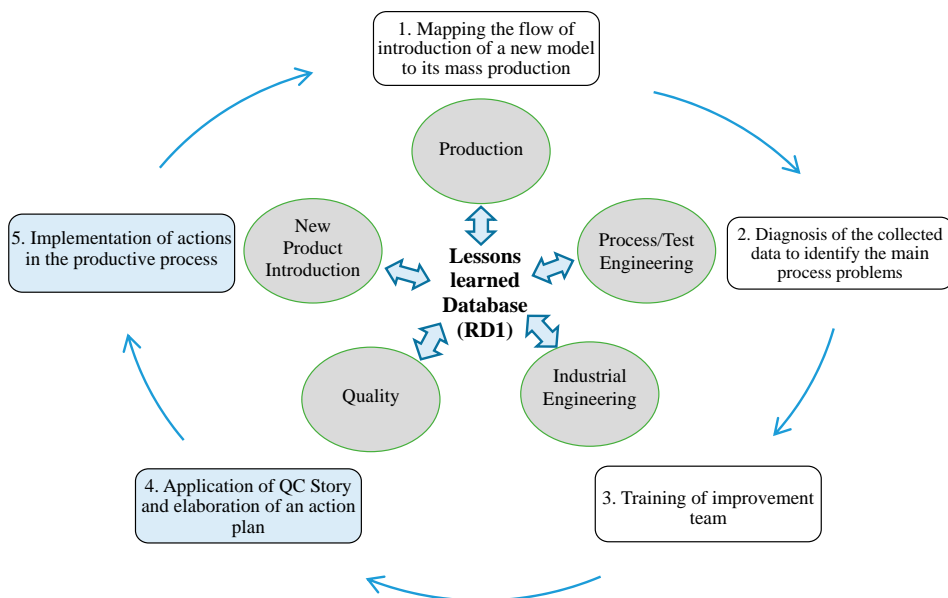


Figure 9. Key activities associated with the use of QC story and lessons-learned procedure.

Additionally, a lessons-learned procedure to record such successful activities is developed and a database is used to record such results (organisational memory), allowing that other plants access and discuss this *lessons*. This information is available not only to quality improvement teams but also to new product/process development teams that make use of this knowledge at early stages of new product /process design (information interpretation).

7. Conclusions

This work presented a practical verification and measurement of the effectiveness implementation of QC story as a method for analysing and solving problems within a multinational large industry, in a competitive sector that manufactures electronic products, over a decade. It also presented a lessons-learned procedure, associated with QC story that contributes to a LO. From this evidence and results from a questionnaire survey, the requirements for improving knowledge management based on QC story towards an LO were induced.

This study provides support for *H1*: the use of QC Story, in a dynamic environment, improves quality performance over long periods (>5 years). This is also confirmed by the questionnaire answers which sentences received an overall positive accordance. The synthesis provided in Section 6 and the specific details provided in Sections 4 and 5 provide an example of how to avoid failure in process improvement as referred by Keating, et al., (1999) and Hicks and Matthews (2010), and through the use of the lessons-learned procedure explain how that level of performance was maintained and improved over time, a relevant challenge identified by Wu and Chen (2004).

According to the researcher observations, collected data and questionnaire results, this research also supports the proposed hypotheses:

H2: Knowledge can be obtained from the activities that constitute QC Story – despite knowledge being intangible, context-specific, relational, dynamic and difficult to grasp. (Wang & Wang, 2016)

H3: A system can be developed based on outputs from QC story usage to perform knowledge storage, retrieval, and transfer – contributing to provide evidence on requirement specifications about its inputs, processes and outputs, as suggested by Lin, (2013) and showing how it can be implemented, as suggested by Despeisse et al. (2012) and Wang and Wang (2016).

H4: QC story team members have the potential to apply knowledge to efficiently solve new problems – this provides evidence to show how problem-solving is capable of developing OL (Tucker et al., 2002) and how the company adapted to a dynamic environment (Yang, 2015).

The main contribution of this work is that QC story can be systematically used as a tool to analyse and solve problems that affect the production process, and along with the presented lessons-learned procedure, improves processes performance over long periods. It is also concluded that this company, using the presented procedure, exhibit characteristics of an LO.

One limitation of this work, by using a single-case study, is the vulnerability in generalising conclusions. Similar studies could be conducted in other manufacturing companies and in service organisations to confirm or refute these positive results in different contexts.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work has been supported by FCT – Fundação para a Ciência e a Tecnologia, through COMPETE: POCI-01-0145-FEDER-007043, within the Project Scope: UID/CEC/00319/2013.

ORCID

Sérgio Sousa  <http://orcid.org/0000-0002-3631-6440>

References

- Antunes, D. L., Sousa, S. D., & Nunes, E. (2013). Using project six sigma and lean concepts in internal logistics. *Lecture Notes in Engineering and Computer Science, LNECS, 1*, 414–419.
- Argyris, C. R. (1977). *Double loop learning in organizations*. Harvard: Harvard Business Review.
- Campos, V. F. (1992). *Controlo da Qualidade Total (No Estilo Japonês)*. Belo Horizonte: DG Editors.
- Chang, D. S., & Sun, K. L. (2007). Exploring the correspondence between total quality management and Peter Senge's disciplines of a learning organization: A Taiwan perspective. *Total Quality Management & Business Excellence*, 18(7), 807–822. doi:10.1080/14783360701349914
- Chen, C., Lu, I., Wang, K., Jang, J., & Dahlgard, J. J. (2015). Development of quality management in Taiwan the past, present and future. *Total Quality Management & Business Excellence*, 26(1/2), 3–13. doi:10.1080/14783363.2014.981071
- Chien, C., Lin, H., & Ya-Hui Lien, B. (2015). Capability contingent: The impact of organisational learning styles on innovation performance. *Total Quality Management & Business Excellence*, 26(1–2), 14–28. doi:10.1080/14783363.2012.746193
- Cho, I., Kim, J. K., Park, H., & Cho, N.-H. (2013). The relationship between organisational culture and service quality through organisational learning framework. *Total Quality Management & Business Excellence*, 24(7), 753–776. doi:10.1080/14783363.2013.791100
- Choi, Y., Kim, J. Y., & Yoo, T. (2016). A study on the effect of learning organisation readiness on employees' quality commitment: The moderating effect of leader–member exchange. *Total Quality Management & Business Excellence*, 27(3), 325–338. doi:10.1080/14783363.2014.981072
- Despeisse, M., Mbaye, F., Ball, P. D., & Levers, A. (2012). The emergence of sustainable manufacturing practices. *Production Planning & Control*, 23(5), 354–376. doi:10.1080/09537287.2011.555425
- Dodgson, M. (1993). Organizational learning: A review of some literatures. *Organization Studies*, 14(3), 375–394. doi:10.1177/017084069301400303
- Fiol, C., & Lyles, M. (1985). Organizational learning. *Academy of Management Review*, 10, 803–813. doi:10.5465/amr.1985.4279103
- Garvin, D. A. (1993). Building a learning organization. *Harvard Business Review*, 71(4), 78–91.
- Garvin, D. A., Edmondson, A. C., & Gino, F. (2008). Is yours a learning organization? *Harvard Business Review*, 86(3), 109–116.
- Gefen, D., Straub, D. W., & Boudreau, M. C. (2000). Structural equation modeling and regression: Guidelines for research practice. *Communication of the AIS*, 4(7), 2–76.
- Guerra, L., Sousa, S. D., & Nunes, E. P. (2016). *Statistical process control automation in the final inspection process: An industrial case study*. IEEE international conference on industrial engineering and engineering management (pp. 876–880), Bali, Indonesia.
- Hicks, B. J., & Matthews, J. (2010). The barriers to realising sustainable process improvement: A root cause analysis of paradigms for manufacturing systems improvement. *International Journal of Computer Integrated Manufacturing*, 23(7), 585–602. doi:10.1080/0951192X.2010.485754
- Hill, F. M. (1996). Organizational learning for total quality management through quality circles. *The TQM Magazine*, 8(6), 53–57. doi:10.1108/09544789610152946
- Hosotani, K. (1992). *The QC problem solving approach: Solving workspace problems the Japanese way*. Tokyo: 3A Corporatio.
- Hussey, J., & Hussey, R. (1997). *Business research*. London: MacMillan Press.
- JUSE Problem Solving Research Group. (1991). *TQC solutions: The 14 step process: Applications* (Vol. 2). Cambridge, MA, USA: Productivity Press.

- Keating, E., Oliva, R., Repenning, N., Rockart, S., & Sterman, J. (1999). Overcoming the improvement paradox. *European Management Journal*, 17, 120–134. doi:10.1016/S0263-2373(98)00072-3
- Kondo, Y. (1990). Key points in quality control training courses for managers. *Total Quality Management*, 1(3), 309–318. doi:10.1080/09544129000000039
- Lam, S. Y., Lee, V. H., Ooi, K. B., & Lin, B. (2011). The relationship between TQM, learning orientation and market performance in service organisations: An empirical analysis. *Total Quality Management & Business Excellence*, 22(12), 1277–1297. doi:10.1080/14783363.2011.631337
- Lee, V. H., Ooi, K. B., Sohal, A. S., & Chong, A. Y. L. (2012). Structural relationship between TQM practices and learning organisation in Malaysia's manufacturing industry. *Production Planning & Control*, 23(10/11), 885–902. doi:10.1080/09537287.2011.642209
- Lin, H. F. (2013). Examining the factors influencing knowledge management system adoption and continuance intention. *Knowledge Management Research & Practice*, 11(4), 389–404. doi:10.1057/kmrp.2012.24
- Lopes, I. S., Nunes, E. P., Sousa, S. D., & Esteves, D. (2011). *Quality improvement practices adopted by industrial companies in Portugal*. Proceedings of the world congress on engineering, WCE, Vol 1, (pp. 696–701), London.
- McAdam, R., & Lafferty, B. (2004). A multilevel case study critique of six sigma: Statistical control or strategic change? *International Journal of Operations & Production Management*, 24(5), 530–549. doi:10.1108/01443570410532579
- Meredith, J. R., Raturi, A., Amoako-Gyampah, K., & Kaplan, B. (1989). Alternative research paradigms in operations. *Journal of Operations Management*, 8(4), 297–326. doi:10.1016/0272-6963(89)90033-8
- Nagaraj, P., & Selladurai, V. (2003). Function approximation of total system cost for a continuous manufacturing system: A case study. *International Journal of Operations & Production Management*, 23(4), 430–439. doi:10.1108/01443570310467348
- Pantouvakis, A., & Bouranta, N. (2017). Agility, organisational learning culture and relationship quality in the port sector. *Total Quality Management & Business Excellence*, 28(3–4), 366–378. doi:10.1080/14783363.2015.1084871
- Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, 88(5), 879–903. doi:10.1037/0021-9010.88.5.879
- Porter, M. E. (1990). The competitive advantage of nations. *Harvard Business Review*, 68(2), 73–93.
- Rossato, I. D. (1996). *Uma Metodologia Para a Análise e Solução de Problemas*. Tese Doutorado em Engenharia de Produção, Universidade Federal de Santa Catarina.
- Senge, P., Dow Michelle, and Neath Gavin. (2006). Learning together: New partnerships for new times. *Corporate Governance: The International Journal of Business in Society*, 6(4), 420–430. doi:10.1108/14720700610689531
- Senge, P., Kleiner, A., Roberts, C., Ross, R., & Smith, B. (1994). *The fifth discipline fieldbook: Strategies and tools for building a learning organization*. London: Random House LLC. ISBN 1-85788-060-9.
- Senge, P. (1990). *The fifth discipline, the art and practice of the learning organization*. New York: Doubleday.
- Silva, R. S. (2016). *Application of QC story in the electronic product industry (Master's thesis in Industrial Engineering)*, University of Minho.
- Silvestro, R., & Westley, C. (2002). Challenging the paradigm of the process enterprise: A case-study analysis of BPR implementation. *Omega – International Journal of Management Science*, 30(3), 215–225. doi:10.1016/S0305-0483(02)00028-2
- Sohal, A., & Morrison, M. (1995). TQM and the learning organization. *Managing Service Quality: An International Journal*, 5(6), 32–34. doi:10.1108/09604529510104365
- Sousa, S. D., Aspinwall, E. M., & Guimarães Rodrigues, A. (2006). Performance measures in English small and medium enterprises: Survey results. *Benchmarking: An International Journal*, 13(1–2), 120–134. doi:10.1108/14635770610644628
- Sousa, S. D., Aspinwall, E., Sampaio, P. A., & Rodrigues, A. G. (2005). Performance measures and quality tools in Portuguese small and medium enterprises: Survey results. *Total Quality Management*, 16(2), 277–307. doi:10.1080/14783360500054434
- Sugiura, T. & Yamada, Y. (1995). *The QC storyline: A guide to solving problems and communicating the results*. Tokyo: Asian Productivity Organization.

- Tague, N. R. (2005). *The quality toolbox*. Milwaukee, WI: ASQ Quality Press.
- Templeton, G. F., Lewis, B. R., & Snyder, C. A. (2002). Development of a measure for the organizational learning construct. *Journal of Management Information Systems*, 19(2), 175–218. doi:10.1080/07421222.2002.11045727
- Tucker, A. L., Edmondson, A. C., & Spear, S. (2002). When problem solving prevents organizational learning. *Journal of Organizational Change Management*, 15(2), 122–137. doi:10.1108/09534810210423008
- Versiani, A., Oribe, C., & Rezende, S. (2013). A aprendizagem das organizações gerada pelas práticas formais no ambiente de trabalho [Organizational learning generated by formal practices in the work environment (original version in Portuguese)]. *RAM. Revista de Administração Mackenzie*, 14(4), 15–44. doi:10.1590/S1678-69712013000400002
- Wang, Y., & Wang, Y. (2016). Determinants of firms' knowledge management system implementation: An empirical study. *Computers in Human Behavior*, 64(2016), 829–842. doi:10.1016/j.chb.2016.07.055
- Wu, C. W., & Chen, C. L. (2004). A new focus on overcoming the improvement failure. *Technovation*, 24(7), 585–591. doi:10.1016/j.technovation.2003.10.010
- Yang, C. C. (2015). The integrated model of core competence and core capability. *Total Quality Management & Business Excellence*, 26, 1–17. doi:10.1080/14783363.2014.991205
- Yang, D., & Rhee, M. (2017). The role of co-production networks in organisations' efforts to enhance the learning curve outcomes. *Total Quality Management & Business Excellence*, 28(12), 1421–1445. doi:10.1080/14783363.2017.1348892
- Yin, R. K. (2003). *Applications of case study research*. *Applied social research methods series*, Vol. 34. London: Sage Publications.
- Yunus, M., Alsoufi, M., & Irfan, M. (2016). Application of QC tools for continuous improvement in an expensive seat hardfacing process using tig welding. *International Journal for Quality Research*, 10(3), 641–660.

Appendix

Survey questions

1. During a project/process where problems need to be solved, teams simulate the problem or possible solutions to learn or to be surer of what to do.
2. During a project/process where problems need to be solved, teams organise into subgroups, invite new entrants, alternate leaders, or make other types of arrangements to function better.
3. To solve the problem, the groups consider the solutions adopted by other organisations, besides those developed in the group itself.
4. Teams often do a comprehensive and in-depth search for existing information about the problem and possible solutions, not to 'reinvent the wheel'.
5. The causes of problems are thoroughly analysed and confirmed with data prior to any decision on the root cause and the solutions needed to eliminate it.
6. Usually, monitoring the performance of the processes in which the teams work is already done, letting the QC story group with the goal of improving an already existing indicator.
7. Teams tend to observe – closely – to gather as much evidence and elements as possible before analysing the problem or defining action plans.
8. When members of QC story groups need specific information, they know where to get them.
9. Teams looking for information and data on problems, causes and solutions know their importance and usefulness of the success of the work.
10. When analysing causes or seeking solutions, teams seek concrete information and data, seeking to base their decisions on facts and data.
11. The areas or departments involved in solving a problem share or exchange information with each other.
12. The members of the improvement groups train the people involved with the proposed solution (Standardisation of work instructions and procedures).
13. When faced with an information the teams present and explore their different possible interpretations.
14. Teams use quality tools (charts, reports, plans, presentation templates, software and other common forms of representation) to facilitate the interpretation of information.

15. When faced with too much information, groups can separate the necessary from the unnecessary.
16. When the solution to the problem substantially alters a procedure or routine, the company eliminates any reference to old practices and replaces them with new ones.
17. When the solution adopted by the group involves a substantial change in organisational practices, people assimilate the novelties and change their behaviour at work.
18. The findings made during the problem-solving process are kept in the form of written documents, procedures, work instructions or other formalisation.
19. Employees use the information and learning generated by Lessons-Learned.

The experience gained by members during the improvement project is passed on to people.