Competencies of Quality Professionals in the Era of Industry 4.0; A Case Study of Electronics Manufacturer from Malaysia

Sumitha Kannan,
Escatec Mechatronics Sdn Bhd

Alaa Garad[1]
University of Portsmouth

Abstract
Industry 4.0 is a buzzword across all industries globally. As the finding from the 'The Future of Jobs Report 2018' (WEF, 2018), there is a narrow window of opportunity between 2018 and 2022 for organisations to leverage the new technology needed to re-skill people. This study investigates the competencies required for quality management professionals to meet the needs of industry 4.0. The authors use a case study strategy at an electronics manufacturer in southern Malaysia to adapt their role to be relevant in the industry 4.0 environment. In doing so, this study answers the following four questions; 1) How are the changing technological trends expected to impact the future role of quality in Industry 4.0? 2) What is the competence gap between current and future roles of quality professionals? 3) What are the views and practices related to quality roles? 4) How can the gaps identified be closed to meet the quality challenges of Industry 4.0? There does not appear to be a specific study conducted using any models to determine the competencies required of Quality professionals. This paper suggests the use of Hecklau et al. (2016) competency model framework to identify the competence gap in a structured manner.

Research Design:
The research methods consist of a comprehensive review of literature on the technological trends towards industry 4.0 and the impact on the role of quality and competence that may be required in the future; as well as internal document review on the current roles of quality professionals in an electronics manufacturer in southern Malaysia, to identify the competence gap. Empirical data was collected based on surveys conducted on 64 quality professionals with a response rate of 96.88% Interviews were conducted on three decision-makers from critical areas in the electronics manufacturer for viewpoints from three different perspectives: finance, operations and talent development.

Key Findings:
Quality professionals will require technical competencies to interpret large amounts of data from processes to make strategic decisions, the use of new Augmented Reality (AR) tools, and be aware of data security risks. Methodological competencies will be required to use data to identify the source of problems, to access reliable sources of learning and the ability to use new tools for solving complex problems efficiently. Social competencies will be required in communications across multi-sites, suppliers and customers in new collaborative virtual platforms, with the ability to retain tacit and explicit knowledge; in a decentralised environment that will require leadership ability to make decisions. Personal competencies required will be the ability to work in a flexible workplace and time and more frequent work-related changes.

Conclusion:
The findings of this study identified the competencies that the quality professionals would require to have to adapt to their role in industry 4.0. The electronics manufacturer appears to be at the first phase

[1] Corresponding Author Alaa.Garad@port.ac.uk

towards the implementation of intelligent manufacturing, and the quality professionals still lack awareness on their role in industry 4.0.

Recommendation:
This study provides recommendations on solutions to overcome the competency gap in the quality professionals to adapt to industry 4.0

Key words:
Industry 4.0, Quality, Competencies, Quality Professionals, Smart factory

Introduction:
Industry 4.0 describes the fourth industrial revolution, which was first mentioned in 2011. The purpose was to develop the German economy based on high-tech strategies; to transform industries by merging digital and internet technologies to conventional industries. About 33% of the industrial sector globally already have a high level of digitization, and the level is expected to increase to 72% in five years (Stancioiu, 2017). Lu (2017) identified the benefits of industry 4.0 to include providing more flexibility, reducing lead times and cost, and customizing with small batch sizes. Benesova &Tupa (2017) explained the implementation of industry 4.0 in four basic phases, as illustrated in fig.1.

The relevance of the study
The purpose of this study is to investigate the current skills and competence of quality professionals and the new skills that would be required to adapt to industry 4.0, by using an electronics manufacturer as a case study. This study may be very relevant and timely to ensure that quality professionals can adapt to industry 4.0 by understanding and working to close the gap in the quality skills and knowledge that is required. Studies on the current role of Quality managers have shown varied perspective on the role of quality including as internal consultants, analyst, trainer, and educators, in leading and supporting improvement work, improving product quality and representing customer voice in the organization (Elg et al., 2011). The quality department is responsible for the overall quality of the products and processes including raw material quality, product, process and outgoing quality; and ensuring the QMS is maintained as per the procedures. Customer quality issues are also led by the Quality teams, working together with operations teams to resolve using quality tools, including 'fishbone diagram', '5Why and 1H', 'SPC', 'Pareto chart' and various other quality tools (Goetsch & Davis, 2016). Therefore, current skills required by quality managers may include communication, teamwork, time management, assessment and analysis, leadership, problem solving, role modelling, decision-making, learning and managing people (Garad, 2007).

The digital age began with the internet and mobile technologies which saw the transformation in businesses into e-businesses, containing e-signature, e-invoice, e-payments. As a result of these disruptive changes with new progresses in robotics and artificial intelligence, many job positions are at risk of being replaced by these new technologies (Dirican, 2015). Lyle (2017) suggested that manufacturers should embrace technology, including, automated data collection and industrial Internet of Things (IoT) to make quality assurance process more efficient.

The effect of these new technologies may already be felt in the Malaysian job market, as declared by Singh, R. (2018), when he quoted Malaysian Employers Federation (MEF) executive director saying that one of the factors of job losses in 2018 will be due to more companies moving towards automation, and usage of robotics and information technology. Kasriel (2017) predicted that there might not be a lack of jobs but a shortage of skills to fill the jobs of the future, Cimini, Pinto and Cavalieri (2017) identified a gap in literature on roles and required skills of the workforce for industry 4.0 and this paper attempts to use a case study to identify the skills gap, and to make recommendations to prepare quality

professionals for industry 4.0. This is an exploratory study and will be followed by other pieces of research using more of mixed methods and larger samples.

First phase: Digital representation in factory in real time
- Full-fledged ERP services
- Increase the volume of stored data
- Data in cloud systems

Second phase Horizontal integration:
- Implementation of automated machines that are connected to networks
- Data can be collected and analysed
- Retraining of company employees to the new machines and data analysis

Third phase: Vertical integration:
- Sophisticated methods for data processing used across the business
- Require business intelligence data analytics

Fourth phase: Self controlling manufacture and logistics
- Autonomous, self-optimizing manufacturing
- Increased communication across global sites, particularly essential for the logistics

Figure 1. Implementation phase by AIMTEC A.S. company (retrieved from: Benešová and Tupa, 2017, pp. 2197–2199).

About the 'electronics manufacturer.'

The electronics manufacturer, which is the context of the case study, is an ISO 9001 certified multinational electronics manufacturer in Malaysia, with headquarters in Singapore. It comprises of 30 companies globally that employs more than 12,000 people worldwide. Amongst its expertise includes printing, imaging and scanning products; RF communications and network; test and measurement equipment; medical devices and life science equipment and retail store solution suite of products. The focus of this study will be on its southern Malaysian manufacturing site, which consists of 9 sites with about 3000 employees. Each site contains a management team with its quality department. This study plans to investigate the quality role across the nine sites.

There is a central Quality Management System (QMS) team that handles the overall company QMS and procedures for the Malaysian sites. However, each site handles multiple customers and therefore, each

site operations may be further customized to meet individual site customer needs. Quality teams in each site are responsible for their incoming material quality, in-process quality to outgoing quality; and customer quality. Elg, et al (2011) observed that the routine focus of the quality department and quality managers include process and audits of operations, providing expertise on new tools and techniques and managing quality management systems. The build and test requirements in customer documents are transferred into standard internal documents by engineers and used by production associates to build the products. With the advent of Industry 4.0, the 'electronics manufacturer' has started to move towards automation of the processes. The Innovation centre of the 'electronics manufacturer' which is based in Singapore, is spearheading the move towards a higher degree of automation and robotics solutions.

Literature Review

According to Lu (2017), scholars have defined Industry 4.0 from a wide perspective, and therefore, no definition that has been adopted unanimously. Benesova and Tupa (2017) suggested that the main vision of industry 4.0 is the appearance of 'smart factories' that are connected to CPS production facilities, which allow machine-machine (M2M), machine-human interaction (HMI) or human-human communication, via Internet of Things, Services and People, through which large amounts of data are generated. These will require highly qualified and educated employees to control these technologies. This idea manifests beyond a single company to across organizations, with data integrated into a cloud and supply chain processes that are organised in virtual space (Szozda, 2017). Qin,et al. (2016, p.174), identified four aspects of manufacturing that had consensus from many researchers as the future visions in Industry 4.0, and they were: a) the *factory*, with intelligent processes in a decentralized system but controlled interdependently, also called a smart factory, b) *Business,* with real-time communication network in supply chain from suppliers, logistics, customers and resources, with real-time responses, c) *Products,* that are smart and carry information that can be analysed, transmit feedback and have the ability to be tracked; and d) *Customers* with ability to place orders in real-time or change orders without charge, and communicate with smart products. Therefore, these four aspects will be used as a framework, to identify the changing trends attributed to Industry 4.0

Changing trends in Factory

People

Industry 4.0 appears to be fully utilizing workers skills and talents instead of moving towards worker-less production. This maybe a key success factor to adapt to the new technologies (Bensova & Tupa, 2017; Gorecky, Schmitt, Loskyll & Zuhlke, 2014). HMI solutions may enable augmented operator in a process to interact with intangible assets and digital contents while acting on the information in the physical world using sensors, to obtain live data from processes, thus allowing operator to have a wider knowledge of the process, including to conduct quality checks (Longo et al. 2017; Wagner et al., 2017). Boeing was able to reduce production time by 25% and with zero errors in their pilot program using a google headset which provided instructions to wire complex electrical systems. (Gaskill, 2017). Quality professionals may also be able to make informed decisions, labour costs and improve quality. (Gaskill, 2017). Therefore, quality roles may move from manual work to automated process that require technical skills (Dal Porto, 2018a,). As pointed out by Evans (2015), quality professionals may need to learn new predictive and analytics tools. Roblek et. al. (2016) suggested 'digital thinking'; to manage processes differently. Education and employee training programs of personnel in the future will also be using virtual resources, for example, google glasses, which educate inspectors by showing diagram and instructions and enable quality inspections to be done 20% faster. Quality management (professionals) may be viewed as a central, strategic role, as change agents and process excellence experts, in the future, as organizations look into value creation for customers and stakeholders, by utilizing innovation (Keim & La Londe, 2017).

The complexity of big data in smart factories, may result in quality professionals requiring to team up with various skill-sets, including IT practitioners, Statisticians and process subject matter experts (SME) e.g. resource managers responsible for AI contents, in order to understand and analyse data and for resource utilization (Boulanger et al., 2017; Longo et al., 2017), for example to analyse cause of machine errors, as well as performing output quality checks to further optimise the processes. (Benesova & Tupa, 2017). This will also enable quality professionals to validate whether machines are learning what they are supposed to be learning (*Smart Factory: Smart Quality Management, n.d., chapter 3*). This is because machine learning appears to depend on the data that is fed, as was the finding by Scientists at MIT Media Lab, where they created an AI psychopath by deep learning algorithm and called it Norman. Norman was fed with dark subject matter data, and then asked to interpret ink blots, with disturbing results: where a standard AI interpreted an inkblot as a vase of flowers; Norman appeared to see a man that was shot dead (McKenna, 2018).

Processes

The smart factories with machines that are cyber-physical systems (CPS) and consists of robots that can self-optimize, self-organise and interact with humans via AR tools and other smart tools; to produce smart products that have controlling and processing capabilities, in a decentralized production. IoT uses big data analytics enabling machine learning and leading to Artificial intelligence capabilities. This may allow for automated quality inspections that enable increased efficiency and product quality in industry 4.0. (Qin et al., 2016; Rojko, 2017; Stancioiu, 2017). For example, Ernst and Young launched a pilot program to use drones for audits to count warehouse stock and collect inventory information that was fed into audit program by using IoT networks (Dal Porto, 2017). 3-D printing processes appear to have an advantage over traditional manufacturing processes by its ability to reduce waste. PriceWaterhouseCoopers (PwC) puts wastage at an average of 21% for traditional manufacturing compared to 10% for 3-D printing. For example, injection moulding requires extra material to fill the moulds, and scrap materials are produced in sheet metal assembly, while 3-D printers use only sufficient material to make the product. Therefore, the technology reduces waste and saves costs (Dal Porto, 2018b,); which is also the fundamental of Lean, i.e. to eliminate waste to improve quality and reduce cost (Goetsch & Davis, 2016). Quality professionals may need the right tools to know how to interpret large volumes of machine data effectively, beyond the current statistical knowledge applications, to be able to make strategic decisions and for training activities). For example, data mining software Waikato Environment for Knowledge Acquisition (WEKA). (Lindborg, 2017; Oliff and Liu, 2017). With the major changes in the technologies in Industry 4.0, new standards may be required to standardize the new terminologies, new processes and controls, for industries to avoid interoperability issues (communication between separate systems) and to ensure uniformity of processes (Trappey, et al. 2017; Lu, 2017).

The social collaboration that enables sharing of best practices and analytics from multiple sources may alert organizations to potential compliance breaches and enable situational decision making by Quality Professionals (Jacobs, 2018). For example, E-learning companies are using cloud-based analytics solutions, enabling their auditors to detect data security breaches in infrastructure that could have security incidents (Corbin, n.d.). This could prevent security incidents as occurred on Facebook. The data breach case of Cambridge Analytica that used Facebook user data without user permission resulted in legal suits filed against both these companies.

Changing trends in Business

The integrated value chain in Industry 4.0 consists of physical material flow across the value chain from supplier input to customer output in the traditional process; incorporated with digital connectivity of data and knowledge transfer through the value chain via IoT (Rojko, 2017; Wagner et al., 2017). As a result of the on-going digitization, automation and customers' expectations for higher degree of customization

and flexibility; companies require to buld strategic alliances with suppliers and competitors to stay competitive. This leads to increased complexity of the processes; where future business networks are expected to respond to other sections in the network in real-time and optimizing profits by sharing a certain amount of resources (Hecklau et al., 2016, p. 3; Qin et al., 2016). For example, a Chinese company, Alibaba, became the biggest internet retailer in China, by providing an e-commerce platform for other businesses to trade in, which enabled overseas customers to buy from Chinese suppliers (Christopher, 2016). New technologies such as RFID and AutoID increase quality and efficiency by providing detailed, real-time information and reduces counterfeiting by efficient communication and traceability of products (Roblek et al.,2016). It may also allow mistake-proof purchasing and minimising incoming quality worries of incorrect parts purchased as purchase orders are automatically loaded to the required parts, when stock levels are low (Wagner et al.,2017). To have this visibility, quality professionals must familiarize with business communication tools, and IoT platforms for communication management include business applications such as ERP and CRM; and web applications such as social media. (Szozda, 2017). Lyle (2017) used the case of Takata airbag recalls in the automotive industry to show how aggregated data in cloud systems from value chain may be able to quickly help quality professionals in manufacturer sites to identify the affected products that required to be recalled, thereby, mitigating the cost of a complete recall.

Changing trends in Products

Smart objects equipped with microelectronics, sensors, actuators, communication and processing modules are able to communicate with the physical world to process data (Wagner et al. 2017). Smart products carrying information, communicating with humans and transmitting information back to the manufacturing systems enable design and processes optimization. This enables continuous improvement activities to be effectively driven by Quality professionals to achieve overall product quality. By tracking and monitoring product performance and usage based on the information log, designers will be able to predict customer usage and maintenance requirements of the product (Lu, 2017, and Qin et al., 2016). Roblek et al., 2016) gave an example of how information from the vehicles on the roads, including the distance from other vehicles, road conditions and weather conditions enable prediction of dangers, to provide notifications to drivers. There will also be increased product variants to produce customized products, which will require high flexibility in manufacturing processes, made possible by cyber-physical production systems (Schötz, et al., 2017). In the future, the ability of smart products to collect customer information based on the interaction with the product usage may lead to privacy and cyber security concerns that also need to be addressed (Hecklau et al., 2016). Also, with smart products that can self-direct down a new path based on machine learning capability, the information may need to be embedded into the process and routed to trained teams to access and make decisions on operational quality risks (*Smart Factory: Smart Quality Management, n.d., chapter.4*).

Changing trends in Customers

In industry 4.0, customers have control over what they purchase, the quantity of products purchased, and the ability to change orders at any time during production without additional costs. Smart products not only provide customers with product information on usage but also utilization of the products as suited to the customer needs (Qin et al., 2016). Customers will also have higher awareness and demands of quality and reliability of products with access to information and technical details of products (Roblek et al., 2016, p.7). Quality professionals need to be more flexible in understanding and managing customer needs (Goh, 2015; Szozda, 2017). Goh (2015) observed that with online purchase capabilities, customer identity would not be easily defined in a globalized world and customers may be faceless characters with computers in another part of the world; encompassing diverse cultures, expectations, preferences and practices. Trends of individual customer demands may lead to increased individualization of manufactured products, and increased market volatility due to changing customer expectations and needs (Hecklau et al., 2016; Schotz et al., 2017). Quality professionals may need to be prepared to meet these

expectations (Qin et al., 2016; Roblek et al., 2016). Quality professionals may analyse customer satisfaction using text analysis tools for big data analysis. An example was provided by Duarte (2017) of how a pizza restaurant resolved their specific pizza delivery issue from analysing customer comments in social media[2].

Competence Requirements in Industry 4.0

Benesova and Tupa (2017) noted that the workforce of the future plays a necessary role in the success of factory innovations, to ensure the success of industry 4.0. Prifti et al. (2017) observed that the transformation in industry 4.0 will require employees to have a wide range of competencies; this gap in competence was also noted by Hecklau et al. (2016), and a competence model was developed for companies to meet the challenges of industry 4.0. Hecklau et al. (2016, p.2) defined competencies as 'a set of skills, abilities, knowledge, attitude and motivations an individual need to cope with job-related tasks and challenges effectively'. A list of core competencies required by employees to cope with the specific job and tasks in Industry 4.0 was derived, divided into the four main established categories of competencies: *Technical, Methodological, Social and Personal* to create a competency model tool to assess specific competencies of individual employees, by customizing it to specific department or job profile, and to identify the competence gap. This paper will use the Hecklau et al. (2016) model as a framework to investigate the gap in the competence of quality professionals, specifically, in the 'Electronics manufacturer' to cope with challenges of Industry 4.0, with the competency requirement coded as per table 1 (in appendix C) .These changing trends and impact to quality have been tabulated in Appendix B

Research Methodology:

The strategy for this research was a mixed-method study design of collecting quantitative data by using a survey questionnaire method, and qualitative data by semi-structured interviews; and content analysis method (Chu & Ke, 2017; Creswell, 2012); from literature texts, on-line data and internal document review, to investigate from a pragmatist perspective. There are several types of mixed method research design. In this research, a combination of Parallel design where qualitative and quantitative data are collected simultaneously (survey questionnaire and semi-structured interview) and embedded design where one form of data (document review) supports another form of data (survey questionnaire and semi-structured interview) was used (Creswell, 2012).

Document review:

We used document review to investigate changing technological trends and its impact on the future role of quality, and to identify the competence gap. Competence required by Quality professionals in industry 4.0 was investigated using secondary source text data from various technology and quality journals, as well as other authoritative articles (Walliman, 2011), by using the Latent Content Analysis research method. Some of the keywords for the literature sample search may include 'Future of Quality', 'Internet of Things (IoT), '3D printing', 'Autonomous Robotics', 'Big data Analytics', 'Cloud Computing', 'Cybersecurity', 'space economy', 'Industry 4.0' 'quality competency' and 'Digital economy' to identify the future and quality role as defined in these literatures, using a purposive sampling method, which is the most commonly used method in content analysis study. (Satu, et al, 2014). Competence of current quality professionals was investigated at the electronics manufacturer by reviewing the internal Quality management procedures from the organization database (Saunders et al., 2015). The 'responsibility' section of the procedures was scanned for the specific reference to the role of Quality professionals by searching specific keywords including 'Quality Manager', 'QA', 'Quality Engineer', 'Supplier Quality', 'QMS Engineer' to identify the current responsibilities (Fisher, 2010).

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From the results of the literature review, Hecklau et al. (2016) competency model framework was used to identify the competence gap in a structured manner, and the result was tabulated in table 1 (in appendix c) .

Survey Questionnaire:

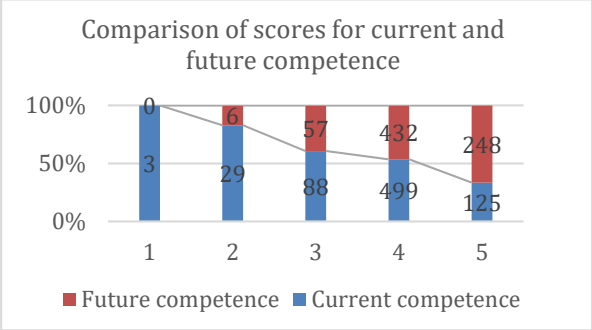
The views and practices related to Quality roles were identified by Survey Questionnaire and structured interview. The questionnaire was based on theoretical propositions that were derived from the gap identified in table 1 (in appendix C). Likert scale questions were used in this survey questionnaire, to allow respondents to indicate how strongly they agree or disagree with a series of statements (Rowley, 2014). The scale was coded '1' to '5', from 'strongly disagree' to 'strong agree'. The respondents were required to tick in the appropriate space (Fisher, 2010). The Questionnaire instrument designed in a manner to investigate current quality competencies (Section A) and future quality competencies (Section B) of quality professionals, from the perspective of the Quality professionals. The survey questionnaire was given to all quality executives, engineers and quality managers across the nine sites as per the database in the Human Resource (HR) department, to ensure all the required participants were included in the survey. With 64 quality professionals, it was a reasonable and manageable number to survey 100% of the population. With a 95% confidence level, and 5% margin of error, the minimum sample size will be 44, with a targeted response rate of 88% for 50 samples (Saunders et al., 2015). The questionnaire was given to the Quality leader of each of the nine sites, to distribute and the questionnaires collected back from the leader within a stipulated due date. Therefore, this ensured anonymity and better response from each site. Before the actual survey, pilot testing was conducted on four people, to ensure the questions could be understood and data recorded by the respondents (Saunders et al., 2015).

Structured Interview:

As per the questionnaire, the interview questions were also based on theoretical propositions that were derived from the gap identified in table 1 (in Appendix C) The participants identified for the interview were by purposive sampling, to meet the objectives, where judgment was used to select cases that best answered the research questions and provide rich data as opposed to statically representing the target population (Saunders et al., 2015). Before the actual interviews, a pilot was conducted by interviewing a senior manager of the company to ensure the questions were clear (Saunders et al., 2015). The interview participants were three decision makers from key areas in the electronics manufacturer for viewpoints from three different perspectives: finance, operations and talent development.

Findings:

The documentary analysis from literature review to identify the gap between current and future quality professionals identified eight gaps (TC1, TC2, TC4, TC6, MC7, MC8, PC1, PC3), as shown in table 1 (in Appendix C). Twelve propositions were derived from these gap results (Appendix A), and these were used in the questionnaire and interviews for further investigation. The response rate to the questionnaire was a high of 96.88% (62 employees) compared to research findings from Since the sample was from 100% of the population of quality professionals in the electronics manufacturer. Therefore, the high response rate provides high confidence that the data is representative of the community. The questionnaire analysis provided the Quality professionals views on the competency gap, and the overall result shows an increasing trend toward 'Strongly agree or Likert scale 5' by more than 66% (248 points) of respondents, in the Questionnaire response towards future competencies, B, compared to 33% (125 points) for current competencies, A (Table 2). All the 12 propositions showed the same median and mode at 4. Therefore, other parameters, e.g. the IQR, range and mean were used to make conclusions in the findings, and by using Mann-Whitney test because it is a non-parametric data significance test between two independent group to investigate if they are related, (Albers, 2017; Singh, K., 2007). Based on mode and median at 4, though, it strongly suggests that participants agree on all the competencies in the propositions in both section A and B.



Likert scale	Current competencies (A)		Future competencies(B)	
1	3	100.00%	0	0.00%
2	29	82.86%	6	17.14%
3	88	60.27%	58	39.73%
4	499	53.60%	432	46.40%
5	125	33.51%	248	66.49%

Table 2: Comparison current and future competencies based on questionnaire result

The findings of each proposition from the questionnaire were triangulated with findings from document review and interviews as follows:

Proposition T1

Quality Professionals will require increased job knowledge due to increased responsibility from manual to an automated process in the production

No significant changes in the process knowledge required between current (A1) and in the future (B13), in the view of the respondents. Similarly, Mann-Whitney test, P-value > 0.05 indicated the difference between the medians is not statistically significant (Fail to reject H_0 that the difference between the median of A1 and B13 =0), although the mean values for A1 are marginally higher than B13, indicating a higher process knowledge requirement at present. The Questionnaire analysis result showed higher process knowledge requirement at present. However, both the Finance Director and Operations head indicated that there would be an increased knowledge requirement in the future. Based on the questionnaire, quality professionals agree that there is a need to understand processes even in the present. This is because current processes are required to continually improve to improve product and service quality (Goetsch & Davis, 2016, p.7). The second aspect addresses the state-of-the-art or new knowledge requirement in the future. With this regard, the questionnaire result shows no difference in requirement in the future due to possible lack of exposure of quality professionals to industry 4.0, but senior management has a different view. The finance director suggests increased knowledge requirement on industry 4.0 as well as to acquire knowledge in financial aspects related to profit and loss, and business awareness. Operations head also feels there is a need of increased knowledge by vertical and horizontal integration to acquire sufficient knowledge to better protect the intellectual property of company and organization due to the data that will be handled by Quality professionals. Talent development head pointed to personal skills and willing to adapt to change, as well as IT skills required for industry 4.0.
The document analysis agreed with the findings confirming a gap in the current quality professionals in the state-of-the-art knowledge, TC1. An example of new knowledge would be 'digital thinking' for managing processes, as was suggested by Roblek et al. (2016, p.3). Automated processes may change the role of workers to coordinators and problem solvers, and therefore, they need to be technically skilled in decision making. (Brettel, et al. 2014; Dal Porto, 2018a,). Therefore, the finding does confirm that increased job knowledge would be required to understand the processes in industry 4.0, for Quality professionals to make better quality decisions.

Proposition T2

Quality professional role transforming from operational to a strategic role, as a change agent, and to identify value creation opportunities for stakeholders

Mann-Whitney test result showed P-value > 0.05, indicating the difference between the medians is not statistically significant (Fail to reject H_0 that the difference between the median of A2 and B14 =0). However, based on IQR difference and a higher number of 5's for B14, there appears to be a shift that future role of quality (B14) will be more strategic, to identify value creation opportunities for stakeholders, which is also reflected in the Likert scale distribution chart. Based on the results from questionnaire and document review, there is a gap in the competencies, i.e. the future role of quality will be more strategic. The finance director agreed that the future role of quality would require more knowledge of all aspects of business, including business and accounting, to be strategic. The Operations director appeared a bit more sceptical as it would depend on the extent the company is prepared to develop the competencies; as well as the structure of the organization, as flatter structures would allow quality professionals to have access to information to make strategic decisions. This may be achievable in the Industry 4.0 model of factories as a decentralized system; as was suggested by Qin et al. (2016). Other factors, as indicated by the talent development head include a plan and capability to utilise structured and unstructured data, to enable internal auditors to have a higher level of understanding of business processes and operations, to provide strategic advice. This was also the finding by Corbin (n.d.) The research finding from ASQ/IAQ concurs that quality is becoming a competitive differentiator and therefore, quality management requires to be in a central part of top management (Keim, & La Londe, 2017). A study by the Research Group on Quality and Organizational Excellence at the University of Minho in Portugal which surveyed quality professionals worldwide to learn their perspectives on the profile of the quality professional in the 21st century also suggested that leadership skills are the most relevant for forthcoming quality leaders (Domingues, P., Sampaio, P., Correia, F.D.V. & Uzdurum, I. , 2020).

Proposition T3

Quality Professionals will require higher technical and media skills to the use of new technologies, e.g. data mining software for big data, Augmented Reality (AR) tools, like smart glasses.

Mann-Whitney test result of P-value < 0.05 (H_0 rejected, the difference between the median of A3 and B15 is not equalled to 0), concludes a statistically significant difference in median for A3 and B15. There appears to be a shift towards a strong agreement by respondents that quality professionals will require higher technical and media skills to the use of new technologies, as part of future competencies. Both questionnaire and documentary analysis results agree there will be a higher technical and media skills knowledge requirement in the future for quality professionals. This was also the expectation from quality professionals from the study by Zavadska & Zavadsky, (2018), where it is expected new augmented media tools such as smart gloves, smart watches and smart tablets may be used in quality management.

Although agreeing to the need of higher knowledge, the Finance director voiced the concern that current (Malaysian) education system cannot provide the knowledge and skills, and it may be required to feed off the Singapore counterparts who is ahead in moving towards industry 4.0. This concurs with a report published in 2015 by the Manufacturing Institute/Deloitte, that there is a lack of importance placed on Science, technology, engineering and mathematics (STEM) skills (Dal Porto, 2018a,). Siti Nur et al (2018) argued that there has been a drop in the performance of science and mathematics performance of Malaysian students to below international between 1999 and 2011, on international assessment tests such as the TIMSS and PISA. Similarly, the Operations head agreed on the lack of talents. However, he placed the responsibility on the employer to provide the skills upgrading to the new technology. Although not widely seen presently, talent development head agreed that skills development and higher order thinking would be required due to the increasing complexity of the shop floor that provides new

challenges to the workers with different user-face technologies. Sung (2018) suggested a different educational system may need to be introduced to meet the requirement of new skill sets, although older workers may not benefit from this approach, and may take need more time to resolve. In summary, the proposition is accepted although there is a concern on how the higher technical and media skills knowledge will be imparted, and who should be leading this challenge, i.e. the industry or Government.

Proposition T4

Due to the use of IoT technology and information on servers, there is a need for Quality professionals to be aware of data security

Mann-Whitney test results P-value < 0.05 (therefore, H_0 rejected, the difference between the median of A4 and B16 is not equalled to 0), concludes a significant difference in median for A4 and B16. There appears to be a shift towards a stronger agreement by respondents that future competencies will require awareness of data security amongst Quality professionals. Both questionnaire and documentary analysis conclude there is a competency gap in data security knowledge in Quality professionals. Both the Finance director and Operations head agreed that quality could play a role in data security audits, which may help to provide confidence to customers. Talent development head voiced concern that the data may be in the external entity and security risks may need to be assessed by auditors. Information security is a crucial aspect of industry 4.0 as the on-line integration of several entities makes cyber threats a shared problem which could result in substantial loss and effect to reputation of manufacturers (Sung, 2018; Tupa, et al., 2017); therefore, justifying the inclusion of data security in an audit program. The Malaysian Government is aware of the lack of cyber security knowledge and Multimedia Minister, Mr Gobind Singh Deo, indicated that there are plans to develop Malaysia to lead within the ASEAN region in providing robust resources for advanced cybersecurity analytics and forensic resources and enhance preparedness of national cyber security, by promoting programs to encourage graduates to take up cyber security as a career ("Malaysia expected", 2018). Therefore, the proposition is accepted on the need for data security awareness, and data security knowledge to be instilled in Malaysians generally, and for Quality professionals, specifically.

Proposition M1

Quality professionals need to examine a large amount of data to identify the source of problems to improve complex processes

Mann-Whitney test result P-value (adjusted for ties) < 0.05: (Therefore, H_0 rejected, the difference between the median of A5 and B17 is not equaled to 0), concludes a significant difference in median for A5 and B17. There appears to be shift towards stronger agreement by respondents that there will be a need in the future to examine a large amount of data in order to identify source of problems to improve complex processes, based on the bigger mean and the higher value for Q3 at 5 for B17 compared to 4 for A5, due to higher number of 5(35.48%) in B17. Although quality professionals agreed that in future quality professionals would require examining large amounts of data to improve complex processes, based on questionnaire result; the documentary analysis did not see this as a gap. This could be because current quality professionals are already required to have problem-solving skills (MC3) and analytical knowledge (MC6), for statistical decision-making (Goetsch & Davis, 2016), However, in industry 4.0, the data from products and processes will be vast and complex, requiring employees to have the capability to identify the appropriate data which would be most beneficial to solve particular problems; and using predictive analysis (Roblek, 2016; Sung, 2018). Therefore, this proposition is accepted.

5.6 Proposition M2

Quality Professionals need access to reliable sources for continuous learning in the changing environment

Based on Mann-Whitney test, P-value > 0.05: (Fail to reject H_0 that the difference between median of A6 and B18 =0), but based on IQR difference, with Q3 value of 5 and a higher number of 5's (29.03%) for B18, there appears to be marginal shift in agreement by respondents that future quality professionals will need access to reliable sources for continuous learning in the changing environment to adapt to industry 4.0.

There is a marginal agreement by Quality professionals that there may be a need to access reliable sources in the future, and this finding supports the documentary analysis that there is a gap to access reliable sources for continuous learning, to adapt to industry 4.0. In industry 4.0, self-directed learning, with the ability to control and correct work autonomously and unaided use of learning content by employees; would enable work-based learning, where reliable information should be readily available from the processes. This agrees with the suggestion by Benesova and Tupa (2017) that the education system should be to Education 4.0, to combine real and virtual world information, to adapt to industry 4.0. It is expected that the approach to learning will change drastically in the coming years due to the higher skills required and with reliable sources of learning, for example, AR that can deliver knowledge in the right place and time (Gaskill, 2017). Therefore, the proposition is accepted, that quality professionals will require access to reliable sources of learning.

5.7 Proposition M3

*With a large amount of data and technology, Quality professionals must be able to solve complex problems more efficiently, with new tools***.**

Mann-Whitney test results P-value < 0.05: (H_0 rejected, the difference between the median of A7 and B19 is not equaled to 0), concludes a significant difference in median for A7 and B19. Based on IQR difference, with Q3 value of 5 and a higher number of 5 (43.55%) in B19, there appears to be shift towards stronger agreement by respondents that future quality professionals must be able to solve complex problems more efficiently, with new tools. Both Questionnaire results and documentary analysis agree that there is a competency gap for future quality professionals to solve complex problems efficiently. All three senior personnel agree on this point, with Finance director suggesting that the tools be developed by Quality professionals themselves and data analytics courses to be in mainstream engineering and quality courses. Operations head suggested AI type of tools. Talent development head raised the concern that it could be costlier to make mistakes in the future with big data sets, and quality and monitoring functions need to be in-built for big data. Currently, quality professionals in the electronic manufacturer use Excel and where applicable, SPC tools like Minitab, which will not be sufficient to analyse big data. To generate meaningful information, advanced tools (analytics and algorithms) that can provide insightful data with correct content may be required (Sung, 2018, p.41). Therefore, this proposition is accepted.

5.8 Proposition S1

Increased virtual work requires improved virtual communication capabilities for listening and presentation when working with a global team, customers and suppliers which quality professionals deal with.

Mann-Whitney test result P-value > 0.05: (Fail to reject H_0 that the difference between median of A8 and B20 =0), but based on the bigger mean value, IQR difference, Q3 value of 5 and higher number of 5's (32.26%) for B20, there appears to be a marginal shift towards stronger agreement in future, that virtual work require improved virtual communication capabilities for listening and presentation, when working with a global team, customers and suppliers which quality professionals deal with. Only a

marginal shift in the questionnaire towards indicating a gap, but documentary analysis confirms no gap in the requirement for increased virtual work for working with global teams, customers and suppliers. This could be because the current organization is already able to access virtual tools, for example, Skype and WhatsApp, for communication with other global sites, including customers and suppliers globally, and there is already some understanding of various cultures in the electronics manufacturer, due to the multiracial nature of the employees. Industry 4.0, however, enables quality professionals to attain enterprise visibility throughout the supply chain, therefore, enabling optimization of operations by having visibility of supply chain performance (Lyle, 2017). A standardized interface may need to be developed to enable collaborative work over different platforms (Hecklau et al., 2016).

Proposition S2

Effective knowledge retention and exchange within the company of tacit and explicit knowledge required due to changing demographics (fewer young people entering the workforce) in industry 4.0

Mann-Whitney test results P-value < 0.05: (H_0 rejected, the difference between the median of A9 and B21 is not equalled to 0), concludes a significant difference in median for A9 and B21. There appears to be shift towards stronger agreement by respondents that there is a future need for effective knowledge retention and exchange within company of tacit and explicit knowledge, based on the bigger mean and the higher value for Q3 at 5 for B21 compared to 4 for A9, due to higher number of 5 (30.65%) for B21 compared to A9.

The questionnaire results indicate a significant need for effective knowledge retention and exchange, although documentary analysis did not find this as a competency gap. This is because effective knowledge retention may not be dependent on industry 4.0. In industry 4.0 however, centralized data may enable the quality managers to have access to necessary knowledge as required to make proactive decisions (Lyle, 2017). Appropriate training strategies and organization of work may be one of the priority areas of actions to foster life-long learning and continual professional development (CPD), for the realization of industry 4.0 (Liao, et al., 2017). Organizations that recognize their employees steadily growing knowledge and utilize the experience in problem-solving to achieve goals, have a competitive advantage (Smith, 2001), although transferring the tacit knowledge to AI may be a challenge as most of the skills we practice daily are unconscious and difficult to articulate; but AI developers have developed a process called 'deep learning' which is making it possible (Waldrop, 2018). Therefore, the proposition is accepted, for organizations to retain and exchange tacit and explicit knowledge in industry 4.0.

Proposition S3

Industry 4.0 environment of more responsible tasks and flat structures will result in every employee becoming a leader (making decisions in the decentralized environment)

Mann-Whitney test results P-value < 0.05: (H_0 rejected, the difference between the median of A10 and B22 is not equaled to 0), concludes a significant difference in median for A10 and B22. There appears to be shift towards stronger agreement by respondents that more responsible tasks and flat structures will result in every employee becoming a leader, in the future, based on the bigger mean and the higher value for Q3 at 5 for B22 compared to 4 for A10, due to higher number of 5 (29.03%) in B22 compared to A10.

Questionnaire result point to an agreement that future quality professionals will become leaders, in a flat structure, although the documentary analysis did not see this as a competency gap. This is because current quality professionals are already required to make certain decisions, e.g. in qualifying suppliers (SC8 in Appendix A). By 2022, augmentation of jobs may result in employees being released from searching and data processing functions, and towards increased decision-making and reasoning functions (WEF, 2018). Both finance director and Talent development head agreed that future quality

professionals would need to be leaders, although finance director feels current climate does not allow employees to be leaders due to the lack of maturity to make informed decisions. This is as agreed by Oliff and Liu (2017) that there is a lack of understanding and competence of advanced manufacturing techniques by the employees in most companies. Operations head similarly feels that processes may allow decisions to be made but should still be routed to superiors for verification. Talent development head suggested breaking up processes into manageable parts to enable clear roles and responsibilities for making and executing critical decisions. The proposition, therefore, can be accepted, but subject to the effective implementation of industry 4.0 at the electronics manufacturer, that will enable quality professionals to have sufficient knowledge to make decisions as leaders.

Proposition P1

Quality professionals will be required to be flexible in the workplace and time, due to the increased virtual work environment

Mann-Whitney test result P-value (adjusted for ties) < 0.05: (H_0 rejected the difference between the median of A11 and B23 is not equalled to 0), concludes a significant difference in median for A11 and B23. There appears to be shift towards more robust agreement by respondents that in the future, Quality professionals will be required to be flexible in workplace and time, due to virtual work environment, based on the bigger mean and the higher value for Q3 at 5 for B23 compared to 4 for A11, due to the higher number of 5 (27.42%) in B23 compared to A11.

Both questionnaire and documentary analysis result indicate future quality professionals will be flexible in workplace, and time, due to a virtual work environment. The finance director agreed that virtual communication tools and future newer virtual tools would enable flexible working arrangements. According to the operations head, it is possible if there are fully automated systems that allow employees to access information without being physically in the production area. Talent development head agreed that it could allow employees to work virtually in the future with mobile systems to monitor the work. Still, the negative impact is that it may affect employee work-life balance. For example, employees of the BMW factory in Leipzig are equipped with mobile tablets to provide access to all data in real-time (Kochan, 2006, as cited by Szozda, 2017). If employees are expected to bring the tablets home, this may intrude into their home life. Therefore, boundaries need to be set to ensure that work does not intrude into the private life of employees (Hecklau et al., 2016). There is also concern some employees may not adapt to the new technology so quickly. However, the younger generation of employees appears to be well adjusted to the use of technology, like smart devices and current telecommunication technology. Therefore, this proposition is accepted. With the recent global impact of the Covid-19 virus, CEO of industrial innovation technology specialist PTC, believes augmented reality will be at the heart of the new 'working normal' as industry has been forced to adapt quicker than it probably would have done under normal economic circumstances (Williamson, J., 2020).

Proposition P2

Quality professionals must be motivated to learn to adapt to more frequent work-related changes

Mann-Whitney test result P-value > 0.05: (Fail to reject H_0 that the difference between the median of A12 and B24 =0), indicates the difference between the medians is not statistically significant but based on the bigger mean value, IQR difference, with Q3 value of 5; and a higher number of 5's (35.48%) for B24, there appears to be a marginal shift towards a stronger agreement by respondents that future quality professionals must be motivated to learn to adapt to more frequent work-related changes; although this could be offset by a higher value of 3 for B24.

Documentary analysis indicates that this is a gap and future quality professionals may need to adapt to more frequent work-related changes. The finance director sees two aspects to the frequent changes due to technology. First is the willingness of organizations to invest in the new technology, and second, the fear of new technology that it may result in job loss, which may cause resistance to change. Operations head pointed out that the company is already implementing on-line learning to enhance further the learning process, which may increase employee curiosity to learn. Examples of implementation in the company include e-quote and e-PCN from suppliers on changes; and an e-leave app downloaded in the employee phone to apply leave. Talent development head suggested changes like new visualization tools that can communicate information more effectively could be used in the future. An estimated 75 million jobs may be displaced due to the shift in the division of labour between human and machines and therefore, by 2022, i.e. in less than five years, at least 54% of employees will need an upskilling (WEF, 2018). Consequently, it is imperative for quality professionals to be motivated to learn to adapt to the changes. Although the electronics manufacturer has started taking small steps in the direction of using technology for all employees, for example on-line e-learning and introducing apps on mobile phone for leave application; there is a long way to go to achieve industry 4.0 ready status and all employees, including quality professionals will need to adapt to the changes, in time. Therefore, the proposition is accepted.

Summary

All the 12 propositions were accepted based on the research and findings from the literature, on the competency requirement of Quality professionals in industry 4.0. The research found that quality professionals will require increased job knowledge due to the interactions with machines and to interpret live data from processes (Wagner et al., 2017). Quality professionals will also require higher media skills to enable the use of AR tools to improve the process and machine performance (Gaskill, 2017). With the vast and transparent data from connected systems and use of cognitive technology, quality professionals may have access to enormous information to identify risks and provide strategic advice to the organisation. However, the increased sharing of large amounts of data across value chains may result in increased risk of data security breaches which quality professionals will need to be aware of (Corbin, n.d.).

Quality professionals will require to be skilled at identifying the source of problems from a large amount of data, to solve complex problems. For example, ensuring complex deep learning algorithm for machine learning are meeting the intended purpose. To have suitable competencies, quality professionals will require access to the reliable source of information, for example, by working with subject matter experts and technical experts (Boulanger et al., 2017; Longo et al., 2017). Quality professionals may need to learn to use new tools, for example, data mining software, WEKA (Oliff and Liu, 2017), to be more efficient in solving problems. It appears the quote from Quality guru, W. Edward Deming: "*In God we trust, all others must bring data.*" (http://quotes.deming.org/authors/W._Edwards_Deming/quote/3734) is most appropriate as we gear up towards industry 4.0; as data appears to be the primary driver of industry 4.0.

With the virtual connection across multi-sites and the value chain, quality professionals will have increased interactions across various virtual platforms in real-time, in industry 4.0, and there will need to be higher virtual communications capabilities. For example, dealing with virtual customers that are no longer well defined, and maybe from diverse cultures (Goh, 2015). With increased decentralization, quality professionals will need to be leaders, to make decisions with the help of artificial intelligence technology (Corbin, n.d.). Due to the complexity and less young people entering the workforce, effective knowledge retention is required and needs to be transparent to enable sharing of best quality practices in organizations (Dal Porto, 2018a; Lyle, 2017). With increased virtual work and the use of mobile apps on phones and tablets, information from the processes may be available quickly to quality professionals,

resulting in the ability to make decisions at any time or place in the virtual, flexible, fluid environment. Quality professionals require being motivated to continuously keep up with the changes in the work environment (Hecklau et al., 2016).

Conclusion

The purpose of this paper was to determine the competence gap of current quality professionals in the electronics manufacturer with the competencies required in industry 4.0. This led to the third objective, to identify the views of stakeholders based on the propositions derived from the gaps identified, to triangulate the findings, to conclude the competency gaps of the current quality professionals in the electronics manufacturer. Finally, the objective of this paper was to make a recommendation on how to prepare the quality professionals in the electronics manufacturer for their role in industry 4.0. The research identified the technical, methodological, social and personal competencies gap of the quality professionals in the electronics manufacturer by looking at the changes expected in industry 4.0 from four aspects, factory (people and process), business, product and customers. This research helped to identify the role of quality in industry 4.0 and key competencies that the quality professionals in the electronic manufacturer will require to adapt to their role in industry 4.0. However, based on the questionnaire and the interview comments of key personnel, it can be concluded that quality professionals lack knowledge of their new roles in industry 4.0 as suggested by Finance head that they would need to work with the Singapore counterparts[3]. This could be due to the new technology is not implemented by quality professionals but by the Innovation team based in Singapore headquarters. However, the full implementation of the industry 4.0 will require significant investment to establish and maintain an IoT infrastructure (Roblek et al. 2016), and the electronics manufacturer appears to be adapting in stages starting with e-learning, e-leave, e-PCN and e-quote. The benefit of industry 4.0 technology is clearly shown by Philips's new Dutch factory with robotized technology that was able to produce the same output with one-tenth of the workers of its China factory (Rifkin, 2014). Rojko (2017) also shared a similar view that Industry 4.0 is expected to reduce production costs by 10-30%, logistics costs by 10-30% and quality management costs by 10-20%. The importance of this research can be seen from the findings of "The Future of Jobs" (2018) that suggests the window of opportunity for organizations to leverage the new technology to re-skill is from 2018 to 2022, to enable employees to reach full potential in the high value-added tasks. The electronics manufacturer may need to keep to this timeline to maintain its competitive advantage.

Limitations

The understanding of the industry 4.0 technology is from the concepts extracted from the literature review based on the knowledge of the researcher. However, technology is still evolving, and the limitation of the study is based on what we currently know of the future, which may not be much for the quality professionals in the electronics manufacturer, who have not been exposed much to the technology yet. The potential for the future landscape to change dramatically with rapid technology changes may also result in a different set of skills for future quality professionals. The quality professionals that were used in this case study were the Quality executives, engineers and managers, irrespective of their gender, age, length of service and experience in the field of quality. Therefore, these variables were not taken into consideration for this research. Besides, quality supervisors and associates were not included, as they do not play a significant role in decision making in the current organizational structure.

Recommendations:

[3] In T1 Finance and Operations director agrees on the need for increased knowledge of Quality professionals (indicating lack of knowledge) and in T3 Finance director suggested to work with the Singapore counterparts (Innovation team which is spearheading the activities, information which was edited out from previous revision).

The re-training of employees in the electronics manufacturer is expected to start at the 2nd phase when intelligent automation is beginning to be implemented (Benesova and Tupa, 2017), as in Fig. 1. The recommended solutions to overcome the competence gap is summarized in Table 3. This includes creating awareness, by exposure to the new technology via attending exhibitions, external training or in-house demonstrations of the latest tools and software by suppliers (Benesova and Tupa, 2017). Training on IT and data security risks (Tupa et al., 2017), as well as access to enterprise data for quality audits, may be provided by the IT department. Access to knowledge may be made possible via mobile assistants and AR tools (Gaskill, 2017; Gorecky et al., 2014) that is provided to employees. Centralized data may help to ensure effective knowledge sharing and storage (Lyle, 2017). Clear work regulations from the human resource department (Hecklau et al., 2016), after getting inputs from all stakeholders; may help quality personnel adapt to the new flexible work arrangements. Quality managers may also need to learn to change their management style from power-driven to value-driven management style in the new environment and learn to motivate employees to adapt to frequent work-related changes (Erol et al., 2016).

The research scope is limited to the electronics industry by using the electronics manufacturer as a case study. However, different sectors may be impacted in different ways by the changing technology, and therefore further studies may be needed on the competencies requirement based on various industries. The size and structure of the company may be another consideration in the implementation of industry 4.0. Employee age may also be a consideration to adapt to the new technology, as generally, young employees appear to be more tech-savvy (Sung, 2018). Artificial intelligence and thinking robots are no longer a part of science fiction movies as we move towards industry 4.0. However, the knowledge of the robots is from the data that is programmed by humans, and therefore, how do we ensure no human bias is programmed into the robots? Thus, another area for future research could be how quality professionals can play a role to ensure the integrity of information and future auditable standards on data integrity that may need to be introduced for this purpose.

Competence	What is required	Suggested Actions to be taken	Responsibility
Technical skills:			
1. Increased job knowledge due to automated processes	**Require knowledge of the automated processes**	**Awareness training, exposure to new technology by attending exhibitions, supplier demo, etc**	**Top management and Innovation team**
2. Strategic role as change agent and to identify value creation opportunities	**Require knowledge from processes to align with business goals and objectives**	**Audit with new big data capability to have access to enterprise level data (Corbin, n.d.)**	**Quality department/ IT department**
3. Higher technical and media skills for new technologies	**Require knowledge of media tools**	**Machine/equipment suppliers to conduct on-site training (Benesova &Tupa, 2017, p.2198)**	**Supplier**
4. Awareness of data security	**Require knowledge of IT and how data security is breached**	**Training on cyber security and data integrity and risk management (Tupa et al., 2017, p.1224)**	**IT department/ Quality department**
Methodological skills:			
1. Ability to solve complex problems by examining large amounts of data	**Require knowledge to analyze big data in order to intepret and solve**	**Training in big data analysis using new tools (Benesova &Tupa, 2017, p.2198)**	**Supplier**
2. Reliable sources for continuous learning	**Require access to the new knowledge**	**Have a personal assistant/mobile device to retrieve relevant information and/or AR (Gorecky et al., 2014,p. 292, Gaskil, 2017, p.11)**	**Quality department/ Innovation team**

3. Ability to solve complex problems efficiently, with new tools	**Require capability for efficient problem solving, with new advanced tools (analytics and algorithms)**	**Training to maximise value using new tools and software, by supplier (Benesova &Tupa, 2017, p.2198, Sung, 2017, p.41)**	**Supplier/ Training department**
Social skills: **1. Increased virtual communication capabilities**	**May require knowledge of new virtal tools across platforms and value chains**	**Training in new virtual tools and platforms(Benesova &Tupa, 2017, p.2198)**	**Training department/ supplier**
2. Effective knowledge retention	**Require effective knowledge sharing and storage**	**Centralizing data from all components of a smart factory in a Quality intelligence solutions (Lyle, 2017, p.8)**	**IT department**
3. Ability to make decisions as leaders in decentralized environment	**Require to read and understand process information from machines**	**Machine/equipment suppliers to conduct on-site training (Benesova &Tupa, 2017, p.2198)**	**Supplier**
Personal skills: **1. Ability to be flexible in work and time due to virtual work environment**	**Require work regulation to have work-life balance**	**Drafting of work regulation for industry 4.0 environment (Hecklau et al.,2016, p.3)**	**Human Resource**
2. Be motivated to adapt to frequent work related changes	**Require Quality managers to to motivate their teams and manage diverse employees, even virtually**	**Training for managers to change management style from power-driven to value-driven (Erol et al., 2016, p. 14),**	**Training department**

Table 3: Recommendation for the competency gap solutions

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Appendix A: Theoretical Propositions for survey questionnaire and interview questions from Literature Review

Proposition	Hecklau et al (2016) template

T1. Quality Professionals will require increased job knowledge due to increased responsibility from manual to automated process in production	TC1, TC3
T2. Quality professional role transforming from operational to strategic role, as change agent, and to identify value creation opportunites for stakeholders	TC2
T3. Quality Professionals will require higher technical and media skills to the use of new technologies, e.g. data mining software for big data, Augmented reality (AR) tools, like smart glasses.	TC4
T4. Due to the use of IoT technology and information on servers, there is need for Quality professionals to be aware of data security	TC6
M1. Quality professionals need to examine large amount of data in order to identify source of problems to improve complex processes	MC3, MC6
M2. Quality Professionals need access to reliable sources for continuous learning in the changing environment	MC7
M3. With the large amount of data and technology, Quality professionals must be able to solve complex problems more efficiently, with new tools	MC8
S1. Increased virtual work require improved virtual communication capabilities for listening and presentation, when working with global team, customers and suppliers which quality professionals deal with.	SC1-SC4
S2. Effective knowledge retention and exchange within company of tacit and explicit knowledge required due to changing demographics (less young people entering workforce) in industry 4.0	SC7
S3. Industry 4.0 environment of more responsible tasks and flat structures will result in every employee becoming a leader (making decisions in decentralized environment)	SC8
P1. Quality professionals will be required to be flexible in work place and time, due to increased virtual work environment	PC1
P2. Quality professionals must be motivated to learn to adapt to more frequent work related changes	PC3

Appendix B: Literature Review summary (see attached)

Category	Changing trends in Industry 4.0	Quality impact	Literature review	Quality professional Competency required in Industry 4.0	Competencies Requirement based on Hecklau et al. (2016)model
Changing trends in Factory - People	VR and AR interfaces for Human machine interactions (HMI) AR gear providing visual cues on machines from an IoT enabled machine on issues, whether repairs required	New tools for information sharing and gathering by sensor based live data on processes. Save organizations time and labour and accurate machine diagnosis Provide graphic diagrams, instructions and information to perform quality checks 20% faster. Reducing production time and errors to zero. visualizing data for Data analysis. Increased use of smart technology e.g. Smart tablet, smart phones, smart glasses and smart gloves will be used in future for various reasons. Up to 25% for Quality control and 16% in non-conformity management. Skilled workers: moving away from manual labor to technically skilled workers	Wagner et al (2017) Gaskil (Feb 2017) Závadská & Závadský(2018) Dal Porto (Jan 2018)	1. New tools: AR and VR competencies 2. Real-time process data gathering 3. Decision making based on visual cues from AR 4. Technical skills for smart device use. 5. Flexibility to adapt to technical skills	**Technical competencies**-state of the art knowledge (TC1) **Technical Competencies**-Process understanding (TC3) **Methodological competencies**: Decision making (MC5) **Technical competencies:** Technical skills (TC2) **Technical competencies:** Media skills (TC4) **Personal competencies**: Flexibility (PC1)
-	Virtual learning and Augmented reality (AR) glasses. Holograms as 3-D blueprints for machine repair. AR lenses/glasses	Education using virtual resources. Employee training programs and factory-floor efficiency. Knowledge delivery to the right place and time. Quality training for	Benešová & Tupa (2017). Gaskil (Feb 2017) Keim & La	1.Higher qualifications and skills requirements to use new technology and smart media	**Personal competencies**: Ambiguity tolerance (PC2) **Personal competencies**-Motivation to learn (PC3) **Methodological skills**: Research skills (MC7)

		value creation Predictive analytics for Quality professionals	Londe (2017) Evans (2015)	 Predictive analytics tools	 Methodological competencies: Analytical skills (MC6)
	Colloboration for AR/AI applications	*Collaborate with Resource manager and Service manager in monitoring and processing inputs from AR devices.* *Teamwork between quality practioners and IT practitioners, Process SME, Statisticians, end consumers required.* *Knowledge for development of 'Digital thinking'*	Longo et al. (2017). Boulanger, et al. (2017, September). Roblek et al. (2016).	Teamwork and collaboration across cross-functional teams	**Social competencies:** Ability to work in a team (SC5) **Methodological competencies**: Analytical skills (MC6)
	Strategic Quality	Quality as central and strategical issue for success (pg. 15), quality professionals as central part of top management in order to move from problem-solving to value creation function.	Keim & La Londe (2017), Antony, (2013)	Leadership competencies. Communication skills. General business skills, including accounting and marketing.	**Social competencies**: Communication skills (SC3) **Social competencies**: Leadership skills (SC8)
	Embedded microchips under skin using RFID-compatible microchip technology. Sensor embedded staff badge to track employee interactions, processes and postures Heat identifies, cameras that monitor space use and ergonomics. Future even monitor stress through heart rate and respiration.	Employees able to unlock doors, log in to computers, make purchases in office minimart. Sensor embedded badges enhance processes, employee engagement and teamwork. Help monitor work place activities and conditions to make better decisions on re-inventing and improving work spaces, team structures and training programs Stress and lack of rest can affect productivity	Edmund (Sep 2017)	Smart device competency	**Technical competencies:** Media skills (TC4)

Category	Changing trends in Industry 4.0	Quality impact	Literature review	Quality professional Competency required in Industry 4.0	Competencies Requirement based on Hecklau et al. (2016)model
Changing trends in Factory - Process	-Digital factory, Virtual simulation of design and functionality developed in parallel with manufacturing. -Robots Conscious, intelligent factory to predict and maintain machines	-Improved product quality. -Quality inspection by robots Machines control the production process and manage the factory in a decentralized system	Stanciou (2017) Qin,et al (2016).	Data analysis and digital skills	**Methodological competencies:** Analytical skills (MC6)
		Re-engineering of production processes Colloborate with Process engineers on Improvement of automated processes,analyzing causes of errors and output quality monitoring	Benešová & Tupa (2017).	Re-training for new automated machines. Responsibility, logical thinking and decision making	**Personal competencies**: Ambiguity tolerance (PC2) **Personal competencies-** Motivation to learn (PC 3) **Methodological competencies**: Decision making (MC5)
	Cloud computing and IoT to have gapless information flow	Large amounts of data directly out of machines to identify unstable process parameters or avoid quality issues.	Wagner et al (2017)	Predictive maintenance and monitoring of machine performance by data analysis	**Methodological competencies:** Efficiency orientation (MC8) **Methodological competencies**: Problem solving (MC3)
		Important contributor to scalability which enables storage and correlation across disparate types of data that are accessible globally, without the need to manage software on premise.	Dan Jacobs (2017)	Scalable software solutions for quality management	**Technical competencies:** Understanding IT Security (TC6)

	Big data	Data mining principles focus on improving product and process quality, using Waikato Environment for Knowledge Acquisition (WEKA) software. New tools for data analysis for big data may be required to effectively use big data.	Oliff & Liu (2017) Antony, (2013) Lindborg (Aug 2017)	Software knowledge for data mining Data analyst New statistical tools knowledge	**Technical competencies**-state of the art knowledge (TC1) **Methodological competencies:** Analytical skills (MC6)
-	Standards for Industry 4.0	New standards and terminology for industry 4.0 to ensure data integrity and quality. Automated compliance which include conforming to regulatory, industry and customer -Social collaboration provides mechanism to share success and failed approaches to compliance across groups, sites and regions. -Analytics to alert organizations on potential compliances breaches - data driven approaches to automate audit-ability.	Boulanger et al. (2017, September). Trappey, et al. (2017). Jacobs (2017)	New Management Standards Automated Compliance knowledge Networking skills	**Technical competencies**-state of the art knowledge (TC1) **Personal competencies**: Sustainable mindset (PC5) **Personal competencies**: Compliance (PC6) **Social competencies:** Networking skills (SC4)
Category	**Changing trends in Industry 4.0**	**Quality impact**	**Literature review**	**Quality professional Competency required in Industry 4.0**	**Competencies Requirement based on Hecklau et al. (2016)model**
Changing trends in Business	Iot Technology, Customer orders automatically loaded and tracked by RFID technology.	1. RFID technology for automatic identification and traceability 2. Automatic cloud data storage of Incoming material records. 3. Aggregated data from value chain to identify and streamline recall process.	-Szozda (2017) -Schötz et al (2017). - Lyle (2017)	1.Communication 2. SAP and ERP to monitor and track incoming information and supply chain performance 3. Manage and analyze incoming database in cloud systems	**Social competencies:** Communication skills (SC3) **Technical competencies:** Technical skills (TC2) **Methodological competencies:** Analytical skills (MC6)

	Cyber-physical JIT balancing material stock on live data. Material movement detected by sensors.	JIT and gapless information flow from supplier to manufacturing process. Mistake-proof purchase, and Increased level of traceability and process reliability.	Wagner et al. (2017)		**Social competencies:** Ability to be compromising and cooperative (SC6) **Social competencies**: Networking skills (SC4) **Technical competencies**: Understanding IT Security (TC6)
	Analyse supply chain data in current enterprise technology and MES system using ML/AI with Incoming inspection data and supplier final test data.	Identify issues with the suppliers' manufacturing processes before suppliers do, enhancing non-conforming material process and impacts supplier risk profiles	Dan Jacobs (2017)		
Changing trends in Products	Smart products embedded with sensors which carry information and knowledge to convey functional guidance to customers and transmit feedback to manufacturing systems	Full product information log embedded to enable: -product tracking -analysing results from information embedded - data to further optimise design, prediction and maintenance -Machine learning and operational risks	Qin,et al. (2016). Roblek, et al.. (2016). Smart Factory: Smart Quality Management	Product data analysis from embedded data, predictive analysis Embedding Operational quality risk into decision process	**Technical competencies:** Technical skills (TC2) **Methodological competencies**: Analytical skills (MC6) **Methodological competencies**: Decision making (MC5)
Category	**Changing trends in Industry 4.0**	**Quality impact**	**Literature review**	**Quality professional Competency required in Industry 4.0**	**Competencies Requirement based on Hecklau et al. (2016)model**
Changing trends in Customers	Mass personalization in real -time.	Meeting individualized customer needs	-Szozda (2017), Goh (2015)	Product knowledge and customer behaviour monitoring.	**Social competencies:** Communication skills (SC3) **Methodological competencies**: Conflict solving (MC4) **Personal competencies:** Flexibility (PC1)

	New purchasing method for customers to order customized products and change orders at any time.	Able to provide better flexibility to manage customers by providing advice on product information/ utilization, to ensure customer satisfaction. Increased customer awareness of importance of quality and reliability of acquired information and technical condition of products	Qin, et al.. (2016). Roblek, et al.. (2016)		
	Text data analysis	Text data analysis for unstructured data using language processing software to search data that can help customer satisfaction analysis and VOC from social media	Jim Duarte (Sept 2017)	Predictive analytics	**Methodological competencies:** Analytical skills (MC6)

Appendix C: Table 1

				Impact of industry 4.0 on future competencies of quality professionals		Competency gap
				Literature review	Electronics manufacturer Internal procedure	
Category	Required Competencies	Context	Code	Future Quality professional competencies required	Current competencies requirement in Electronics Manufacturer	
Technical competencies	State-of-the-art knowledge	Due to increasing job responsibility knowledge is getting increasingly important	TC1			
	Technical skills	Comprehensive technical skills are needed to switch from operational to strategic tasks	TC2			
	Process understanding	Higher process complexity demands a broader and deeper process understanding	TC3			
	Media skills	Increasing virtual work requires employees to be able to use smart media e.g. smart glasses	TC4			
	Coding skills	Growth of digitized processes creates a higher need for employees with coding skills	TC5			
	Understanding IT security	Virtual work on servers or platforms obligates employees to be aware of cyber security	TC6			
Methodological competencies	Creativity	Need for more innovative products, as well as for internal improvements, requires creativity	MC1			
	Entrepreneurial thinking	Every employee with more responsible and strategic tasks has to act as an entrepreneur	MC2			
	Problem solving	Employees must be able to identify sources of errors and be able to improve processes	MC3			
	Conflict solving	A higher service-orientation increases customer relationship; conflicts need to be solved	MC4			
	Decision Making	Since employees will own higher process responsibility, they have to make their own decisions	MC5			
	Analytical skills	Structuring and examining large amounts of data and complex processes becomes mandatory	MC6			
	Research skills	Need to be able to use reliable sources for continuous learning in changing environments	MC7			
	Efficiency orientation	Complex problems need to be solved more efficiently, e.g. analysing growing amounts of data	MC8			
Social competencies	Intercultural skills	Understanding different cultures, especially divergent work habits, when working globally	SC1			
	Language skills	Being able to understand and communicate with global partners and customers	SC2			
	Communication skills	Service-orientation demands good listening and presentation skills, whereas increasing virtual work requires sufficient virtual communication skills	SC3			
	Networking skills	Working in a highly globalized and intertwined value chain requires the knowledge networks	SC4			
	Ability to work in a team	Growing team work and shared work on platforms expects the ability to follow team rules	SC5			
	Ability to be compromising and cooperative	Entities along a value chain develop to equal partners; every project needs to create win-win situations, especially in businesses with increasing project work	SC6			
	Ability to transfer knowledge	Companies need to retain knowledge within the company; especially with the current demographic change, explicit and tacit knowledge needs to be exchanged	SC7			
	Leadership skills	More responsible tasks and flattened hierarchies make every employee becoming a leader	SC8			
Personal competencies	Flexibility	Increasing virtual work makes employees become time and place independent; work-task rotation further requires employees to be flexible with their job responsibilities	PC1			
	Ambiguity tolerance	Accepting change, especially work related change due to work-task rotation or reorientations	PC2			

	Motivation to learn	More frequent work related change makes it mandatory for employees to be willing to learn	PC3			
	Ability to work under pressure	Employees involved in innovation processes need to cope with increased pressure, due to shorter product life cycles and reduced time-to-markets	PC4			
	Sustainable mindset	As representatives of their companies, employees also need to support sustainability initiatives	PC5			
	Compliance	Stricter rules for IT security, working with machine, or working hours	PC6			
Extracted from: Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic Approach for Human Resource Management in Industry 4.0. *Procedia CIRP, 54*(6th CIRP Conference on Learning Factories), 1-6. http://dx.doi.org/10.1016/j.procir.2016.05.102						

Reference Colour code:

	Competencies required by Quality Professionals in Industry 4.0
	Current Quality competency requirement as per Procedure
	Not applicable quality competency for Quality professionals
	Quality professional competency gap

Table 1: Document Review Analysis Result - Quality Competency gap analysis in Electronics Manufacturer

About the Authors:

Sumitha Kannan

QA Manager at Escatec Mechatronics Sdn Bhd

K. Sumitha P. N. Kannan is a Quality professional with over 28 years' experience in the electronics industry. After completing her Bachelor of Science degree majoring in Physics, she went on to work in various Japanese and US electronics multinational companies and is currently attached to a Singapore based electronics service provider. Her work experience includes new Product introduction, Process improvement, Manufacturing and Material management, Customer Support, Quality Management, Subcontract/Supplier management & Logistics support. She is an ASQ certified Quality Manager and Quality auditor, as well as a senior member of ASQ. She has also recently completed her Masters of Science in Strategic Quality Management at the University of Portsmouth.

Alaa Garad, PhD,

Senior Teaching Fellow at University of Portsmouth,

Alaa.Garad@port.ac.uk

University of Portsmouth

Alaa is a Senior Teaching Fellow and Course Leader of MSc Strategic Quality Management at the University of Portsmouth Business School. He is a Senior Assessor and Juror at several Excellence and Quality Awards, accredited Specialist at Investors in People (IIP) the Deputy Chair of the Human Resource Management Technical Committee, British Standards Institution and members in ISO TC/260. Alaa is a strong advocate of quality and learning and has designed and delivered a wide range of courses, workshops and conference papers in the Middle East, Europe and Asia. He is a columnist, a public speaker and the co-author of the Learning-Driven Organisation Model and the creator of the first OL certificated program (COLP). His research Interest includes Organisational Learning, Strategic Quality Management and Business Excellence, ISO Standards, EFQM, innovation management and futures foresight.