An Investigation into how the Science and Engineering Curriculum in Higher Education Institutions Supports Undergraduates Entering the Testing and Certification Industry in Hong Kong upon Graduation

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Copyright Statement

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Glossary

Education Bureau: The government agency that is charged with developing and implementing education policies in Hong Kong. The Secretary for Education heads the bureau. The officeholder manages the Secretariat, Student Financial Assistance Agencies, and the University Grants Committee.

Financial Secretary: The officeholder is the minister in charge of all the financial and economic issues of the Hong Kong administration. The Financial Secretary is one of the senior-most officials in the Hong Kong administration and is responsible for supervising the development and implementation of economic and financial policies in the Hong Kong territory. The officeholder reports to the Chief Executive and Legislative Council of Hong Kong.

Global Competitiveness Index Report: The report examines the ability of nations to improve the living standards of citizens. However, such ability is determined by the extent to which a country efficiently utilises the available resources. The Global Competitiveness Index thus assesses the set of institutions, policies, and factors that set the sustainable current and medium-term levels of economic prosperity.

Higher Education Institute: These institutions offer higher levels of education for which a learner is awarded a degree upon graduation. Institutions of higher learning that also offer more than 2-year programmes are considered higher education institutes.

Hong Kong Council for Testing and Certification: The council oversees Hong Kong's Testing and Certification industry. The primary function of the council is to advice the Chief Executive state of the Testing and certification sector.

Hong Kong Accreditation Service: Hong Kong Accreditation Service provides accreditation for conformity assessment bodies located in Hong Kong, through the Hong Kong Laboratory Accreditation Scheme (HOKLAS), Hong Kong Certification Body

Accreditation Scheme (HKCAS) and Hong Kong Inspection Body Accreditation Scheme (HKIAS).

Hong Kong Council for Testing and Certification: The Hong Kong Council for Testing and Certification was established by the Hong Kong Government. The role is to advise the Chief Executive on the overall development strategy of the industry; new business opportunities worth exploring for the industry, with regards to the latest developments in Mainland China and overseas markets; and measures needed to raise the professional standing and community awareness of the industry.

Hong Kong Housing Authority: Hong Kong Housing Authority is the main provider of public housing in Hong Kong. It was established in 1973 under the Hong Kong Housing Ordinance and is an agency of the Government of Hong Kong.

Hong Kong Institution of Engineers (**HKIE**): Hong Kong Institution of Engineers is a professional body of engineers in Hong Kong. The Institution aims to facilitate the exchange of knowledge and ideas, train the members in new technology and practices, and to raise the standing and visibility of engineers.

Hong Kong Productivity Council: Hong Kong Productivity Council is a multi-disciplinary organisation established by statute in 1967. It aims to promote productivity excellence through the provision of integrated support across the value chain of Hong Kong firms, in order to achieve more effective utilisation of resources, to enhance the value-added content of products and services, and to increase international competitiveness.

Hong Kong Trade Development Council: Hong Kong Trade Development Council is a statutory body established in 1966 as the international marketing arm for Hong Kong-based manufacturers, traders and service providers. The HKTDC is governed by a 19-member Council of Hong Kong business leaders and senior government officials. It plans and supervises the organisation's global operations, services and promotional activities.

Institution of Engineering and Technology (**IET**): Institution of Engineering Technology is the multidisciplinary professional engineering institution. The IET has the authority to establish professional registration for the titles of Chartered Engineer, Incorporated Engineer, Engineering Technician, and ICT Technician, as a Licensed Member institution of the Engineering Council.

International Organization for Standardization (ISO): The organisation is an independent and non-governmental membership organisation that develops voluntary International Standards.

InvestHK: The agency is a department in the Hong Kong Special Administrative Region (HKSAR) Government established in 2007 to attract and retain foreign investment to enhance the economic development of Hong Kong.

Policy Address: Policy Address is the annual address by the Chief Executive of the Hong Kong Council for Testing and Certification.

Qualifications Framework: The framework was developed to help Hong Kong institutions establish clear goals and directions for effective learning and quality-assured qualifications to improve the overall quality and competitiveness of the local workforce. The QF is a seven-level hierarchy of qualifications focusing on the academic, vocational and continuing education sectors.

Quango: Quango defines as a quasi-autonomous non-governmental organisation or is an organisation to which a government has devolved power.

Skills Gap: The difference between the qualifications and competencies of graduates and the competencies and qualifications required in the workplace.

Recognition of Prior Learning (RPL): Recognition of Prior Learning describes a process used by regulatory bodies, career development, human resource, professionals, training, institutions, colleges and universities to evaluate skills and knowledge acquired to recognise competence against a given set of standards, competencies, or learning outcomes.

Testing and Certification: Testing and Certification refers to the verification and confirmation of products such as electronics and electrical gadgets, food products, and medicine by a third-party accredited laboratory to ensure that they meet the established standards.

Third-party Certification: Third-party certification means that an independent organisation has reviewed the manufacturing process of a product and has independently determined that the final product complies with specific standards for safety, quality or performance. This review typically includes comprehensive formulation/material reviews, testing and facility inspections. Most certified products bear the certifier's mark on their packaging to help consumers, and other buyers make educated purchasing decisions.

Testing and Certification: Testing and Certification refers to the verification and confirmation of various products meant for human use such as toys, textile and apparel, food, jewellery, electrical and electronic products, and Chinese medicines by a third-party accredited laboratory.

Abbreviations/ Acronyms

HA:	Hong Kong Housing Authority
HKAS:	Hong Kong Accreditation Service
HKCAS:	Hong Kong Certification Body Accreditation Scheme
HKCTC:	Hong Kong Council for Testing and Certification
HKIAS:	Hong Kong Inspection Body Accreditation Scheme
HKIE:	Hong Kong Institution of Engineers
HKPC:	Hong Kong Productivity Council
HKSAR:	Hong Kong Special Administrative Region
HKTDC:	Hong Kong Trade Development Council
HRPA:	Human Resources Professionals Association
HOKLAS:	Hong Kong Laboratory Accreditation Scheme
IET:	Institution of Engineering and Technology
ISO:	International Organization for Standardization
ITC:	Innovation and Technology Commission of Hong Kong
QF:	Qualifications Framework
RPL:	Recognition of Prior Learning
T&C:	Testing and Certification
SCS:	Specification of Competency Standards

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Abstract

Employability skills and graduate competencies are the issues that continue to dominate discourse surrounding the higher education labour market. One of the key industries in which this discussion has been conducted in Hong Kong is the Testing and Certification (T&C) industry. This industry plays an important role in ensuring that products are safe and of good quality for customers in the Hong Kong Special Administrative Region (HKSAR). Good-quality product testing and certification significantly depend on the competence of employees working in the industry. This research study investigated the extent to which Science and Engineering graduates in Hong Kong had the employability skills and graduate competencies required to work in the T&C industry in Hong Kong. The study was undertaken in two phases sequentially. In phase one, a pragmatic research approach using a mixed-method design was used to examine the extent to which the current Science and Engineering curriculum in Higher Education Institutions (HEIs) in Hong Kong met the specifications of the competence standards of the Higher Education Qualifications Framework (QF) for the T&C industry. Through a document review of key competencies in the QF for the T&C industry as well as the curricula of T&C programmes in the Faculties of Science and Engineering across the universities in Hong Kong, data was subjected to content analysis. By using mixed methods, the data was then further analysed quantitively by tracking patterns on three aspects: i) number of UC courses; ii) coverage of codes of competency; and iii) weight of codes. As a result of the findings obtained from phase one, exploratory research was subsequently conducted to investigate the extent to which Science and Engineering graduates could competently work in Hong Kong's T&C industry. Semi-structured interviews were conducted and the collected data was then analysed thematically.

The key findings of this study showed that the current curriculum for Science and Engineering students in Higher Education Institutions did not enable graduates to meet the competency expectations of the T&C industry. The evidence from the data collected in this study indicated that Science and Engineering graduates lacked some core graduate competencies that would enhance their employability in the T&C industry. However, the recently developed T&C programmes in the Science and Engineering curriculum of three universities in Hong Kong were designed to support the transition of T&C graduates from the classroom to the T&C workplace. In a comparison of T&C graduates with conventional science and engineering degrees, the T&C graduates appeared to have better employability skills and graduate competencies needed for work in the industry. Hence, the evidence from this study indicates that a gap existed with regard to the graduate competency requirements of the T&C industry and the conventional Science and Engineering graduates' competencies. The gaps identified primarily included the implementation of testing, an indication that most conventional Science and Engineering graduates were unable to apply their knowledge practically.

The study concluded that Hong Kong's Higher Education Science and Engineering curriculum should be redesigned to ensure that graduates looking to enter the T&C industry had the employability skills and graduate competencies needed to work in the industry.

CHAPTER ONE: INTRODUCTION

The purpose of this study was to investigate how Science and Engineering curriculum in the Higher Education Institution (HEI) in Hong Kong supports undergraduates entering the Testing and Certification (T&C) industry upon graduation. This research project stems from an interest in the relationship between the Science and Engineering curriculum and job requirements for engaging in the T&C industry.

I am a lecturer teaching undergraduate courses in Material Science and Engineering. Before entering the academic field, I worked as a consultant in a quasi-autonomous non-governmental organisation (quango) to provide testing services, technical consulting services and training to the local electronics industry. Given the high technical requirements of the T&C industry, undergraduates of a Higher Education Institution entering the Testing and Certification industry upon graduation should be well equipped with the skills and competencies needed by the industry. These views are supported by Teichler (2009), who argues that the relationship between initial capitals throughout for Higher Education and employment is increasingly problematic, new tensions are emerging and new perspectives are required. Teichler’s conclusions are further confirmed by Anderson *et al*. (2010), who examined whether the higher education sector is providing graduates with the requisite skills and knowledge to match employment needs in the UK. Anderson *et al.* (2010) noted that Science and Technology is a dynamic and ever-changing field. The difficulty in predicting the direction of scientific advancements, and the economic opportunities that arise as a result of these advancements, as driven by market demand, increasingly challenge the capabilities and flexibilities of science education providers.

The T&C industry was identified by the Task Force on Economic Challenges of the Hong Kong Government as one of the six high-growth economic areas in 2009. Since then, the Hong Kong Government has fully committed to reinforcing the development of the Testing and Certification industry. The Hong Kong Council for Testing and Certification (HKCTC) was established in September 2009 to advise the government on the overall development strategy of the industry and introduce new measures to support the industry's growth. The HKCTC comprises members from the T&C industry, business sector and professional organisations as well as relevant public bodies and government departments (HKCTC, 2010). Owing to the scale and the diverse nature of the T&C industry, the nature of the industry was defined and grouped into three core business areas by the HKCTC:

- Testing: the determination of one or more characteristics of an object according to a procedure.
- Inspection: the examination of product design, product, process or installation and determination of its conformity to specific or general requirements based on professional judgment.
- Certification: a third-party attestation related to products, processes, systems or persons (HKQF, 2014, p.2).

According to the Report of the Hong Kong Council for Testing and Certification (2018), the number of people working in the T&C industry in 2017 was 18,280, with a contribution of HK$7.3 billion to Hong Kong's Gross Domestic Product (GDP). Compared with the GDP in HK$6.5 billion 2014, this indicates there was continuous growth in the T&C industry, and it plays an important role in the daily life of the Hong Kong community as well as in external trade. Because of the growth of the T&C industry, there is a high potential linkage to manpower demand and, in turn, employment opportunities.

The Qualification Framework Steering Committee concluded in 2013 that there was a skill gap between academic qualification and job competencies in the T&C industry. However, there is no information to explain the skill gap. As I am a lecturer teaching undergraduate courses, my concern is whether students have gained the required employability skills and graduate competence to meet the job requirements for the T&C industry in order to increase their employability opportunities as well as enrich their career prospects. My research, therefore, aimed to explore the extent to which the Science and Engineering curriculum in Higher Education Institutions in Hong Kong supports entry into the T&C industry upon graduation.

CHAPTER TWO: RESEARCH CONTEXT

Introduction

This chapter describes the reasons, approach and major stages undertaken and reported in my research. This chapter also sets the scene for this research, illustrating how the development of the T&C industry in Hong Kong relates to Science and Engineering curriculum development.

T&C Industry Profile

The Testing and Certification industry provides testing, inspection and certification services in general. Testing is the determination of one or more characteristics of an object according to a procedure. Inspection is the examination of a product design, product, process or installation and determination of its conformity to specific or general requirements on the basis of professional judgment. Certification is a third-party attestation related to products, processes, systems and persons. The T&C industry is a general term referring to businesses which offer services related to T&C (HKCTC, 2010). The T&C industry has more than 50 years of history in Hong Kong, developing under the voluntary regime of standards and certification that in general models on many other advanced economies. In its early years, the industry focused mainly on providing services for the manufacturing industry in Hong Kong. More recently, responding to end-users changing needs, the scope of T&C services has broadened to other sectors such as food, health care and environmental industries. At present, the major economic activities of the T&C industry are: technical testing and analysis; cargo inspection, sampling and weighting; and medical laboratory services (Census and Statistics Department, 2012). As identified by the Task Force on Economic Challenges (TFEC, 2009) of the government, the T&C industry is one of the six economic areas where Hong Kong has global advantages, has good potential for business development and provides increasing job opportunities.

Entering the T&C Industry

The starting point of this study, therefore, was how Hong Kong's T&C industry can remain globally competitive through a competent and highly skilled workforce. Due to growing market demand as well as job opportunities in the T&C industry, the ability of the current Science and Engineering curriculum to prepare undergraduates effectively for entry into Hong Kong's T&C industry was the main focus of this research study. The Hong Kong Government devotes substantial resources to improving the quality of manpower to further diversify the economy and steer its development towards high value-added activities such as promotion of innovation and technology, manufacturing and service industry development (Budget Policy Address, 2015).

The report published by Invest Hong Kong (InvestHK) (2015) further substantiated the importance of developing the T&C industry, pointing out the advantages and opportunities of Hong Kong to offer world-class, efficient and professional testing, inspection and certification services by the testing laboratories. To ensure that the competence of the testing laboratories is recognised, the Hong Kong Accreditation Service (HKAS) provides accreditation for laboratories, certification and inspection bodies in accordance with the standards published by the International Standards Organisation (ISO). The report also identified some global and local accredited testing, inspection and certification companies in Hong Kong. This research explored the types of employability skills and graduate competence required by Hong Kong graduates who wish to enter the T&C industry. Importantly, for this study, the Qualification Framework Steering Committee concluded in

2015 that there was a skill gap between academic qualification and job competencies in the T&C industry. In order to consider this conclusion, the following research questions have been used to guide my research work:

Overarching research question: To what extent does the undergraduate Science and Engineering curriculum in Hong Kong's Higher Education Institutions facilitate entry into the Testing and Certification industry in Hong Kong?

Two subsidiary questions follow from the main research question:

(i) To what extent does the current Science and Engineering curriculum meet the specification of competence standards of the Qualifications Framework for the T&C industry?

(ii) To what extent, if any, is there a skill gap between the current Science and Engineering curriculum and job competency requirements in the T&C industry?

Structure of My Research Work

The overall context of the research approach involved four stages. The first stage was to consider and establish my epistemological stance, and research positionality as a researcher. The second stage involved a literature review to highlight key areas for further research. Four notable themes arose from the review of literature conducted: 1) Training; 2) Curriculum; 3) Employment and 4) Competency. The third and fourth stages of the research process were the identification of appropriate research methodologies, which led directly from the four themes identified in the literature review that form the basis for employability skills and graduate competencies. The research methodology selected as a result of stage three was the decision to employ a mixed method to collect both quantitative and qualitative data. Through a document review of the curricula of Testing and Certification programmes in the Faculties of Science and Engineering of the universities in Hong Kong, and the key graduate competencies in the Qualification Framework for the T&C industry, a qualitative analysis was initially undertaken, followed by a quantitative analysis of 'pattern'. The findings in the third stage were used as the starting point of the fourth stage of the research project. Exploratory research was conducted to investigate the extent to which Science and Engineering graduates could competently work in Hong Kong's T&C industry. Semi-structured interviews were conducted and the collected data was then analysed, thematically. The overall research approach is summarized in Figure 2.1.

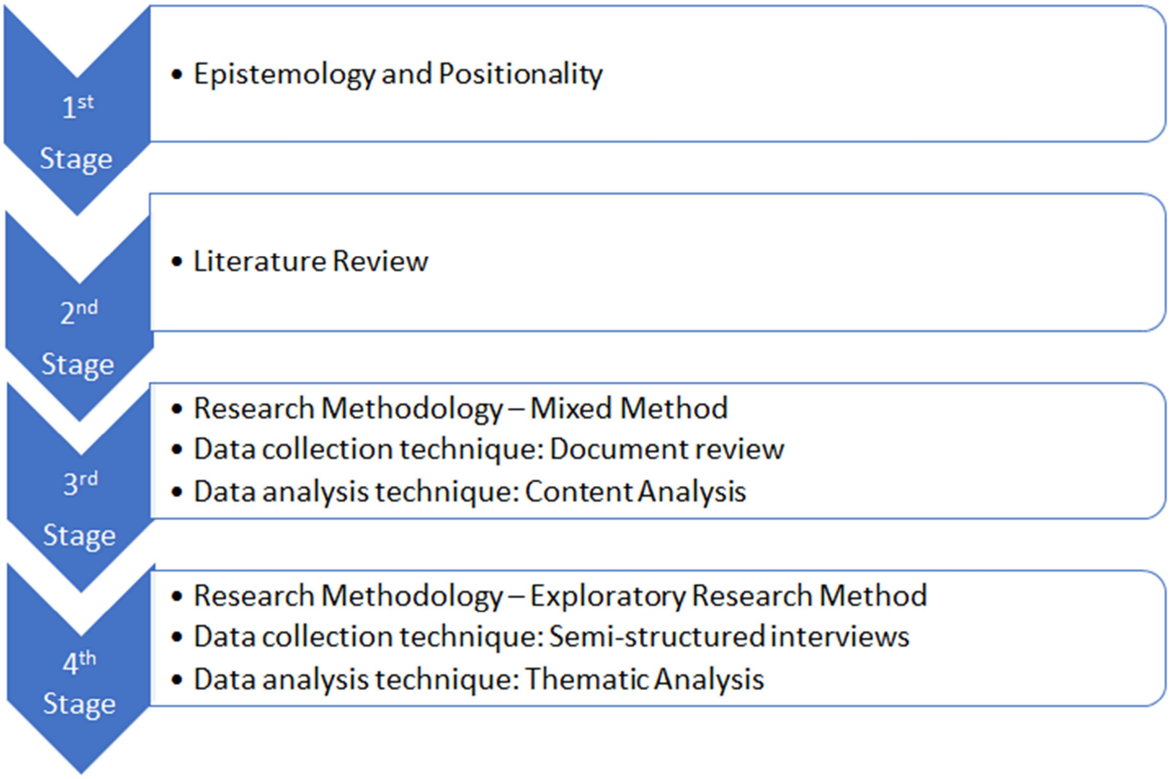

Figure 2.1 Overall Research Approach

CHAPTER THREE: EPISTEMOLOGY AND IDENTITY

An important part of this research project was to give a clear consideration to, and explanation of my epistemological and ontological position as a researcher. Initially, I reflected on who I am as a senior lecturer teaching Science and Engineering, a course developer, and a director of the Recognition of Prior Learning (RPL) Assessment Agency for the T&C industry. Then, I justify for my epistemological stance, given my background studying Science and Engineering disciplines at university, and then consider how graduates in Science and Engineering disciplines might migrate to a professional path. This is to give a clear indication of my epistemological and ontological position as a researcher. Furthermore, the current Science and Engineering curriculum and the extent to which it meets the specification of competency standards defined by the Qualifications Framework for the T&C Industry are investigated.

3.1 Positionality of self within the research endeavour

I am a Senior Lecturer teaching undergraduate courses that focus on Material Science and Engineering. Additionally, I am also the Director of the Recognition of Prior Learning (RPL) Assessment Agency for the T&C industry under the Qualifications Framework of Hong Kong (HKQF, 2016). The major objective of the RPL mechanism is to enable applicants of various backgrounds to receive formal recognition of the knowledge, skills and experience they have acquired while working in the T&C industry. In this context, I am very concerned with investigating the linkage of the current Science and Engineering curriculum with the specification of competency standards established by the Qualifications Framework of Hong Kong (HKQF, 2016).

3.2 My career path after graduation

After graduating with a Bachelor of Science (BSc) degree in Applied Physics, I worked for two years as an engineer in an international electronics manufacturing company, where I was supervised by a senior engineer who was willing to teach me and share his experiences. The knowledge that I acquired pursuing my university degree was essential; and included product design, assembly, production and quality management. However, it was quite challenging to learn various testing requirements and standards for the electronic products that were not taught during my undergraduate study. With such an opportunity, I became aware of the importance of the T&C standards as they are used to maintain product integrity and quality.

3.3 Migration to the professional path

After working for two years at the electronics manufacturing company, I moved to a consultant post at the Hong Kong Productivity Council (HKPC), a quasi-autonomous non-governmental organisation. My role was to provide testing services, technical consulting services and training for the local electronics industry. The HKPC's mission is to promote productivity excellence through the provision of support across the value chain of Hong Kong firms to achieve more effective utilisation of resources, enhance the value-added content of products and services, and increase international competitiveness.

My move from being an engineer to a consultant was challenging because consultation is a professional service offered by experienced and qualified consultants to help organisations solve problems. Kubr (2002) points out that consultation is a professional and advisory service contracted for and provided to organisations by specially trained and qualified persons who assist in an objective and independent manner. He further indicates that a qualified consultant should be capable of identifying and analysing problems and recommending solutions for clients.

Because I was a young consultant with only two years' work experience in the electronics manufacturing field, I encountered difficulties in handling various clients' enquiries and issues. To overcome such difficulties, I worked very hard and proactively looked for opportunities to learn and study. I began to see the importance of professional development and how professional qualifications are related to job competency. I attended training organised by the government and the professional bodies such as the Hong Kong Testing and Certification Council, the Hong Kong Accreditation Service (HKAS), the Institution of Engineering and Technology (IET) and the Hong Kong Institution of Engineer (HKIE). To further broaden my knowledge, I was supported by my company in attending several overseas training events to establish networks and partnership with professional bodies. This was very important for developing my career path in the consulting field.

In 2009, the Task Force on Economic Challenges of the government identified the T&C industry as one of six high-growth economic areas. Since then, the Hong Kong Government has fully committed to reinforcing the development of the T&C industry. In response to the initiatives identified, the HKPC established testing laboratories and provided testing services to support the T&C industry. Hence, I had more opportunities to work extensively in the T&C environment by providing testing services, delivering training, auditing factories and consulting with clients. Due to the demand for high technology and compliance related to T&C disciplines, my colleagues were required to equip themselves by attending different professional training events. Indirectly, the extent to which the current Science and

Engineering curriculum meets the competency requirements in the T&C industry already was taking shape in my mind.

In 2013, there was a significant change in my career path as I joined a self-financed university as a senior lecturer, teaching undergraduate courses on Material Science and Engineering in the newly established T&C department. I worked under an inspiring program leader (my direct supervisor) who embraced change as a positive aspect of course development as well as professional development. During the same year, HKAS appointed me as one of their qualified Technical Assessors to conduct assessments in local testing laboratories in accordance with international standards – ISO 17025. The experience of conducting such assessments was significant, as I gained knowledge in assessment skills and technical requirements in different testing fields (e.g., toy testing, electrical appliance testing, garment testing).

In 2018, in parallel with my teaching role, I worked as the Director of the Recognition of Prior Learning (RPL) Agency for the Testing and Certification Industry. The RPL mechanism was developed under the Qualifications Framework of the Education Bureau. Through regular meetings held between T&C stakeholders and government officials, specification of competence standards were discussed and refined for the T&C industry.

My continuing roles as RPL Director and Technical Assessor not only affords me a professional stance but also offers me the opportunity to understand employability skills, graduate competencies and qualifications that T&C practitioners should acquire during Higher Education study.

According to Jon (2008), a curriculum can be defined as the knowledge and skills that learners require to meet training standards or learning objectives. He posits that an effective curriculum enhances the ability of the learning process to train students and build their skills and competencies with regard to their career goals in a highly competitive labour market. If training is directed toward career goals or particular work in a highly competitive society, an individual requires knowledge of the competencies, qualifications and skills. Hence, my professional stance and experience are important to my research.

CHAPTER FOUR: LITERATURE REVIEW

In undertaking this review of literature, I sought to develop an insight into the role of curriculum construction and the link to employability and graduate competencies. Fielden (2007) and Pegg (2010) are concerned about the transition of young full-time students into the labour market because they argue that those young full-time students enter employment with no work experience and with skills deficits. These claims are supported by Mason, Williams, and Cranmer (2009) who argue that most institutions of higher learning do not focus on employability skills initiatives. And, as a result this hinders the higher education providers ability to produce graduates who are ready for the workplace. According to Yusuf (2014), the skills expected from employees change dynamically with technological and economic developments, the emergence of new industries, and change-of-work processes. These developments require a review of initial capitals throughout higher education programmes at regular intervals and a harmonisation of the skills that graduates must have to meet the expectations of the knowledge economy.

Mismatches arise in the supply and demand of skills in labour markets since people in the education system and work life may not be able to respond to these changes at the same pace. If we accept this point for the mismatches, the relationship between higher education and employment would seem to be increasingly problematic. Wade (2015) argues that the reasons and impact of skills mismatches need to be understood. He further points out that stronger links between businesses and universities are a key foundation for addressing skills mismatches. Such concerns have been identified by the Hong Kong government. The report on ‘Challenges of manpower adjustment in Hong Kong' issued by the Legislative Council Secretariat in 2016 highlights the issue of skills mismatch among graduates of higher education. The fact is that the proportion of the local workforce of Hong Kong with higher education has more than tripled from 9% to 29% from 1994 to 2015, but less than half of them could take professional jobs in recent years. As the creation of higher-skilled jobs for graduates cannot keep pace with manpower supply amidst slow progress in structural change in the local economy towards knowledge-based activities, more graduates with higher education have needed to take lower-skilled occupations. With this, the thoughts of Pegg (2010) and Wade (2015) about higher education and employment underpin the context of my research, so my literature review seeks to identify the linkages of the following:

1. Training
2. Employment
3. Curriculum
4. Competency

4.1 Training

According to Jon (2008), a curriculum can be defined as the knowledge and skills that learners require to meet training standards or learning objectives. The author posits that an effective curriculum enhances the ability of the learning process to support students and build their skills and competencies with regard to their career goals in a highly competitive labour market. As a result, students are better prepared to meet the training expectations of their careers and, therefore, have a greater chance of achieving career success. Drawing on Jon's explanation of a curriculum, he indicates that the ability of the learning process to revise competent graduates and the efficacy of the curriculum are closely linked. The ability of school curricula to meet training needs is, therefore, a major challenge in the education sector. Equally problematics is the inefficacy of a curriculum poses significant challenges to the economy of a country due to the potential limitations of a curriculum to enable students to be prepared to contribute and to improve the productivity (Amue Gonewa, 2014).

According to Amue Gonewa (2014), lack of competent graduates negatively impacts on the ability of a country to achieve its economic growth objectives. For developing economies, this is a major challenge because they are not able to transition into emerging economies without well-trained graduates with the skills to drive economic growth in the modern century.

The competitiveness of a nation is often determined by its ability to perform well and achieve success in international markets. Schwab (2014) argues that highly competitive nations in the international market are characterised by high levels of productivity across various industries and a business environment that supports the growth of the private sector. Such a business environment also attracts foreign companies to invest in a particular country. The 2014 Global Competitiveness Index report placed Hong Kong at position 7 out of 30 countries in the world competitiveness ranking, an improvement from the 11th position that it attained in 2011. A competitiveness report by the International Institute for Management Development (IMD) released in 2016, on the other hand, ranked Hong Kong at position 1 out of 61 countries in global competitiveness. The ranking meant that Hong Kong had improved from the fourth position that it held two years before. Despite the high ranking, Hong Kong still faces several challenges with regard to competing on the global stage. Research commissioned by the Bauhinia Foundation in 2012 showed that while Hong Kong does particularly well in areas such as law, governance and infrastructure, it performs poorly in 'higher order' areas such as education that significantly determines the competence of employees. In 2016, Hong Kong Economic Report also revealed that there is a challenge on the effectiveness of curriculum to prepare graduates that are ready for the labour market. As a result, many graduates take up jobs that require lower qualifications. Therefore, this research study explores the types of training that students should undergo within the Higher Education environment to enhance their ability to meet the competencies and qualifications required to succeed in a competitive economy and especially in an industry such as T&C.

4.2 Employment

There is a considerable amount of literature on graduates' employment (for example, the work of Holmes, 2001; Sumner, Yager & Franke, 2005; Bridgstock, 2006; Kruss, McGrath, 2015). Glen (2009) points out that graduates should be equipped to deal with the demands of a rapidly changing work environment. This could be achieved through the possession of core skills that are assumed to transfer across a range of contexts readily. Barnett (2003) implies that employability and the promotion of 'key' and 'core' skills are a similar set of achievements, understanding and personal attributes that make individuals more likely to gain employment and be successful in their chosen occupations. Watts (2006) also defines employability as a set of skills, knowledge and personal attributes that make an individual more likely to be secure and successful in his or her chosen occupation for the benefit of himself or herself, the workforce, the community and the economy.

A similar view is supported by Lee (2014), who stresses that similar to other public services, higher education in Hong Kong is undeniably under the strong influence of the notion of public accountability. Universities are under constant pressure to be more relevant and responsive to market needs. This is to ensure that graduates learn relevant skills and knowledge to gain employment opportunities.

However, I argue that a graduate should not simply be a carrier of a set of skills, knowledge and personal attributes, but the qualification they achieve and the subjects they study in relation to the demand of employers and of that particular industry should also be significant. Therefore, the required knowledge, skills and qualifications to engage in the T&C industry for Hong Kong graduates is worth studying if they wish to enter this industry.

4.3 Curriculum

Several studies on the science curriculum and its relevance to employment have been conducted over the decades (Duggan & Gotta, 2002; Glen, 2009; Weert, 2011). Russell and Bazeman (1994) assert that the science curriculum emphasises content; it lacks relevance to learners interests and attention to contemporary science issues, and the way scientific knowledge is presented is disconnected from technical know-how. Because of the rapid-changing technologies, Bond and Lamasson (1999) suggest the way knowledge is acquired is also changing. They stress that the growth of knowledge has been largely ‘vertical’ in that once the fundamentals are established, new knowledge is added in a gradual, increasingly specialised way. Young and Glanfield (1998) support this contention, writing in relation to employment that “Under the impact of technology, the skills needed in different occupational sectors are converging as more and more jobs demand generic and abstract rather than sector-specific skills” (p. 7).

One of the possible implications is that the science curriculum needs to be reformed to meet the needs of the rapidly changing technology in the real world. Rae (2007) indicates that one of the main problems faced by universities is the choice of a degree subject and its relevance to the employment market. He observes that universities have the freedom to offer degree courses for which they have the capacity, and they consider they can attract a viable number of students. Doggan and Gotta (2007) argue that universities are not required, either individually or collectively, to offer degree programmes that meet employer skill or workforce planning needs. They argue that the imbalance between the drive to attract students and the lack of any direct need to relate courses to employer demand has resulted in the growth of courses that reflect student fashion resulting in a decline of courses such as sciences, technology and engineering, for which there is employer demand but decreasing student attraction. With this, Malcolm, McInnis and Hartley (2010) explain that science and technology is a dynamic and ever-changing field. The difficulty in predicting the direction of scientific advancement and the economic opportunities that arise in areas of that advancement, as driven by market demand, increasingly challenges the capabilities and flexibilities of science education agencies and testing laboratories. A report published by the European Commission of the Expert Group on Science Education (2015) suggests that Higher Education Institutions should boost the understanding of the importance of science education as a means of acquiring key competencies to ease the transition from 'education to employability' (E2E) by strengthening connections and synergies between science, creativity, entrepreneurship and innovation. Collectively, the thoughts of the earliest researchers, including Young and Glanfield (1998), Bayliss (1999), Rae (2007) and Gotta (2007), as well as the current researchers, including Malcolm, McInnis and Hartley (2010), inspire me to further explore the extent of the current science and engineering curriculum to meet competency requirements and match with the employability of graduates entering the T&C industry.

4.4 Competency

The changing nature of work, the organisational change and the need for graduates to be 'work ready' after graduation have previously been observed to ensure economic competitiveness in a global context. One way of considering work readiness is to examine the extent to which the skills graduates believe they possess at the time of graduation match the skills they consider are needed in their work a few years after graduation. According to Khir (2006), graduates now lack both technical know-how and generic skills, so efforts to increase graduates' competence must cover both areas. In the face of intensive global competition, a growing concern is that current graduates do not match the needs of businesses, leading to skills mismatch. The issue of skills mismatch has received considerable critical attention (Pitan Oluyomi and Adedeji, 2012; Carroll and Tani, 2013; World Economic Forum, 2014; HKSAR, 2016). One possible cause of skills mismatch is the type or level of skills is different from that required to perform a job adequately. Another possible cause is the level of qualification, or the field of qualification is different from that required to perform a job adequately (World Economic Forum, 2014). The issue of skills mismatch has grown in importance in Hong Kong. The Research Office of Legislative Council Secretariat (2016) has concluded that more graduates need to take lower-skilled occupations instead of knowledge-based or professional jobs. As such, I argue that having a close working relationship with the industry is important for the Higher Education Institutions in Hong Kong to meet the requirements and needs of the employers.

<u>Qualification</u>

With respect to growing market demands as well as job opportunities in the T&C industry as reported by the Census and Statistics Department of the HKSAR government in 2012 and 2013, exploring the readiness of the competent bodies (such as the higher education sectors in Hong Kong) in terms of the learning outcomes of a curriculum, the qualification achieved by the undergraduates and the extent of the T&C industry's needs is indeed important. The interplay between

- the learning outcome of a curriculum
- the job competency requirements under QF and
- the T&C stakeholders

is crucial if there is a need to look at the changing professional practice and competence requirements in entering the T&C industry. As such, the notion of Gasskov and QAA merits my further exploration in drawing the concept of qualification by considering the learning outcomes, assessment or validation process, competencies and the T&C industry's needs (Figure 4.1).

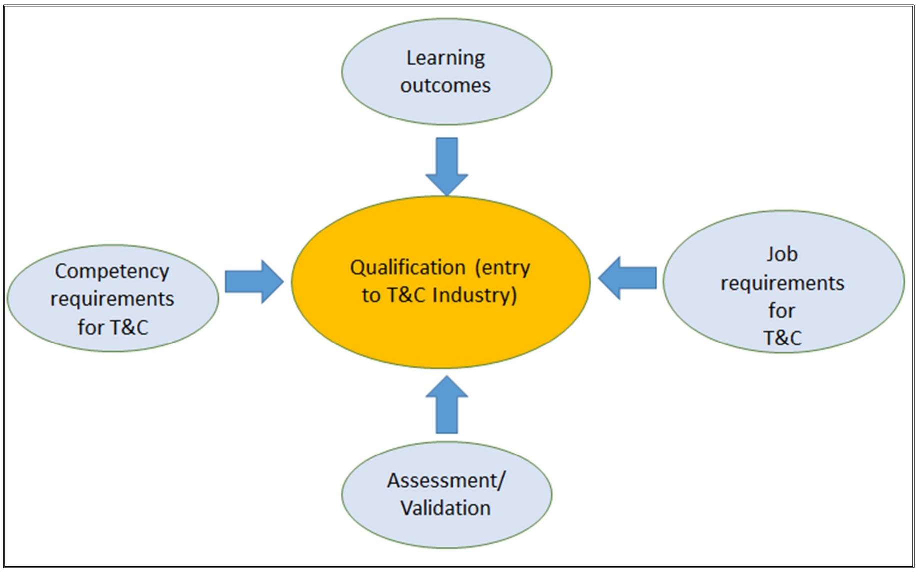

Figure 4.1 Conceptual framework for 'qualification'

Why a Qualifications Framework Is Needed

The Hong Kong Council for Testing and Certification (2014) has reported a lack of a formal professional status for people working in the T&C industry. During their interviews with various stakeholders, a skill gap was found between academic qualifications (e.g., bachelor's degree, higher diploma) and job competencies required by the T&C industry. As a result, the Qualifications Framework was established to recognise the vocational qualifications for the professional development of practitioners in the industry. The function of the QF is to clearly define the standards of different qualifications acquired from academic, vocational and continuing education, ensure their quality and indicate the articulation ladders between different levels of qualifications. Through this research project, I intent to examine the research the competence required by the Qualifications Framework in Hong Kong and the job competence required by the T&C industry.

Competency Standards

The Qualifications Framework Steering Committee in 2014 has developed a set of specifications of competency standards for the T&C industry, which serves as a guideline to training providers, such as universities to develop recognised training programmes, these specifications of competency standards will also be scrutinised as part of this research project. Indeed, competency standards have been established in several countries, including the United Kingdom (QAA, 2014), Europe (EQF, 2014) and Australia (AQF, 2015). The requirements of these standards vary according to the conditions set by the government agency. Similarly, the Qualifications Framework under the Education Bureau of the Hong Kong government has developed the Specification of Competency Standards of the testing, inspection and certification industry in 2014. The Specification of Competency Standards (SCS) is regarded as a set of core competencies for the identified work functions with specifications on integrated outcome performance for the industry. These competency standards are the industry requirements for the skills, knowledge and attributes required to satisfactorily perform a job at a certain qualification level. According to the QF in Hong Kong, the qualification levels are designed in a seven-level hierarchy, which ranks level 1 as the lowest and level 7 as the highest. Based on this hierarchy design, I construct the correlation of the qualifications in the academic sector with the QF levels in Table 4.1.

Table 4.1 QF levels for qualifications in the academic sector (HKQF, 2013)

Qualifications in the Academic Sector	QF Levels in Hong Kong
Doctorate Degree	7
Master’s Degree	6
Bachelor’s Degree	5
Associate Degree	4
Diploma of Secondary Education	3
Secondary Level Certificate	2
	1

Various skill functions are presented as units of competencies (UoCs) in the SCS. The QF elaborates that UoCs are competency-based, contextual and outcome criteria referenced. Each UoC represents an integral, self-contained set of competencies required to perform a specific task. The UoCs can be grouped into building blocks for serving different purposes. Since my research is concerned with undergraduates entering the T&C industry after graduation, the UoCs, as laid down by the QF for qualification levels 4 and 5 (associate and bachelor's degree holders), is the focus of my study.

Taken together, there is a possible link between competencies and employability skills. The issue of employability skills has received considerable critical attention. Cotton (2005) argues that employability skills are job specific, but certain skills cut horizontally across all industries and vertically across all jobs from entry level to chief executive officer. This view is supported by Guy, Sitlington, Larsen and Frank (2009), who highlight that employability skills are those basic skills necessary for getting, keeping and doing well on a job. According to the US Department of Health and Human Service (2003), competencies often serve as the basis for skill standards that specify the level of knowledge, skills and abilities required for success in the workplace as well as the potential measurement criteria for assessing competence attainment. A similar view has been put forward by Sturgis (2014), stating that competence is the capability to apply or use a set of related knowledge, skills and abilities required to perform jobs or tasks in a specific work environment successfully. Sturgis (2014) further indicates that people who have the required knowledge, skills and abilities are eligible to engage in the following three main job categories:

1. Entry level (getting a job)
2. Performance level (keeping a job)
3. Fluent or professional level (doing well on a job)

To focus more on the undergraduates who engage in the T&C industry after graduation, I explore the entry requirements of the T&C industry, whereas issues of how well graduates perform in their job are beyond the scope of my research.

4.5 Research Questions

The research questions include the main research question and two subsidiary questions.

Main research question

My main research question is: To what extent does the undergraduate Science and Engineering curriculum in Hong Kong's higher education sector facilitate entry into the Testing and Certification industry in Hong Kong?

Subsidiary questions

Two subsidiary questions follow from the main research question:

(i) To what extent does current Science and Engineering curriculum meet the specification of competence standards of the Qualifications Framework for the T&C industry?

(ii) To what extent, if any, is there a skill gap between current Science and Engineering curriculum and job competency requirements in the T&C industry?

As I have noted previously, the T&C industry has good potential for business development and providing job opportunities. Due to growing market demand as well as job opportunities, the readiness of the current curriculum to prepare undergraduates entering the T&C industry is a key issue that my research study examines. The literature review shows that higher education curricula should be designed to prepare graduates to effectively transition from the classroom to the workplace. Graduates with the skills and competencies required in the workplace not only help organisations to meet their performance objectives in the market but also drive economic growth in a highly competitive international market. Existing literature does not, however, focus on a specific industry in a specific country with regard to a particular higher education course. This study, therefore, seeks to provide a more context-specific research that examines whether the higher education science and engineering curriculum in Hong Kong effectively prepares undergraduates for employment in Hong Kong's T&C industry.

CHAPTER FIVE: METHODOLOGICAL DISCUSSIONS

The purpose of this research is to reveal the extent to which the undergraduate Science and Engineering curriculum in Hong Kong Higher Education Institutions facilitates entry into the T&C industry in Hong Kong. Specifically, the study addresses the following two research questions as mentioned in the abstract.

(i) To what extent does the current science and engineering curriculum meet the Specification of Competency Standards (SCS) of the Qualifications Framework (QF) for the T&C industry?

(ii) To what extent, if any, does a skills gap exist between the current science and engineering curriculum and the job competency requirements of the T&C industry?

The research methodology was performed in two phases sequentially to examine the research questions. In the first phase, key competencies in the QF for the T&C industry were reviewed and existing T&C programmes in the faculties of Science and Engineering of the universities in Hong Kong were identified. In the second phase, the effectiveness of current Science and Engineering curriculum in higher education was explored in terms of employability skills and graduate competency requirements in the T&C industry.

5.1 Pragmatism as Philosophical Positioning of the Study

In 1977, Kuhn expressed that a paradigm is a set of beliefs, values and techniques shared by members of a scientific community, and which acts as a guide or map, dictating the kinds of problems scientists should address and the types of explanations that are acceptable to them. A paradigm or worldview is ‘a basic set of beliefs that guide action’ (Guba, 1990, p. 17). Based on the above definitions, it is evident that the concept of ‘paradigm’ applies to a higher level than research methodology, which is grounded in research rigour. According to Bryman (2012), the research paradigm is a cluster of beliefs at a higher level and dictates what should be studied, how research should be done and how the results should be interpreted. The thoughts of the researchers show the need to interpret the results logically and systematically, focus on the philosophical justification, and analyse qualitatively and quantitatively.

Pragmatism is the most appropriate research paradigm for phase one because it can be used to examine the research issue effectively.

> ‘To a pragmatist, the mandate of science is not to find truth or reality, the existence of which is perpetually in dispute, but to facilitate human problem-solving.’ (Powell, 2001, p. 884)

Pragmatism as a research paradigm mainly concerns itself with what has been called American pragmatism as seen in the writings of Peirce, James, Dewey and Mead (Scheffler, 2012). Peirce, James, Dewey and Mead considered it an important research paradigm because it enables the researcher to present logical and practical claims, a factor that enhances the credibility and utility of study findings.

Goldkuhl (2003), on the other hand, argued that pragmatism focuses on problem-solving. This view is supported by Pansiri (2005), who studied the methodological approach to researching strategic alliances in tourism. Tourism is one of the most highly integrated industries in the world (Bullock, 1998; Dale, 2000). The T&C industry has a nature similar to that of tourism. Owing to the diverse and highly integrated nature of the T&C industry, this industry is defined and grouped into three core business areas including testing, inspection and certification (HKCTC, 2014). My research explored the readiness of the current Science and Engineering curriculum developed by Higher Education Institutions in Hong Kong to prepare undergraduates for entry into the T&C industry. One of the challenges of my research was to explore any possible skill gap between academic qualifications and job competencies in this industry. Goldkuhl (2003) influenced my thinking about the problem-solving issues relating to the philosophy of pragmatism. For this reason, it was essential that I identify problems such as skills gap in my research study.

Pragmatism as a research philosophy is appropriate for both mixed and qualitative research methods (Burke, Onwuegbuzie and Turner, 2004). This is because such a research approach is concerned with the degree to which a phenomenon occurs, the conditions that give rise to it and the experiences of those affected by it. A mixed method complements quantitative approaches dealing with the issue of experience. According to Goldkuhl (2003), pragmatism requires the researcher to make claims and arguments that are practical and grounded in logic when conducting a qualitative study. The research philosophy, therefore, ensures that the arguments made by the researcher when analysing themes are credible and reliable. Newby (2014) mentioned that the need for pragmatism is paramount as a result of the importance placed on the issue being researched and because of the need to find an answer to a specific question.

5.2 Research Design

The research design plays an important role in determining the reliability of the study findings. Selecting an appropriate research design for the study enhances the objective of determining the efficacy of the science and engineering higher education curriculum in bridging the gap between T&C industry needs and knowledge in the Higher Education Institutions. The research design would thus enable me to understand the strengths and limitations of the existing Hong Kong higher education curriculum with regard to ensuring that students pursuing Science and Engineering programmes are able to transition efficiently to the T&C industry.

5.2.1 Sequential Mixed-Method Design

A mixed-methods approach is the one in which knowledge claims are based on pragmatic grounds (Krippendorff, 2004). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand the research problems (Krippendorff, 2004). The data collection process also involves gathering both numeric and text information so that the final database can represent both quantitative and qualitative information (Creswell, 2003).

Since the main research inquiry of the current study is an investigation into how the current science and engineering curriculum facilitates entry into the T&C industry in Hong Kong, I collected and analysed data based on three key areas: (1) job requirements for the T&C industry, (2) Qualifications Framework competency standards, and (3) the Science and Engineering curriculum. Furthermore, a mixed-methods approach was appealing in that it enabled a variety of research methods to be engaged within the research focus (Johnson, Onwuegbuzie and Turner, 2007). For this particular study, it was not enough to just use a qualitative approach to examine whether the higher education science and engineering curriculum produces graduates that have the skills and competencies required in the T&C industry. The use of a quantitative approach enabled me to examine the elements of breadth and depth with regard to curriculum coverage to establish whether the problem could be in the manner in which higher education Science and Engineering curriculum is covered. The findings in this phase were used as the starting point of my next phase in my research project. Therefore, the mixed methods were divided into two phases by incorporating pragmatism and exploratory research design approaches.

An exploratory research design was used to explore the perceived effectiveness of the current science and engineering curriculum in terms of equipping graduates with job-specific skills in the T&C industry in phase two. Every-Palmer (2011) argued that an exploratory research design is an appropriate research method when there is little data available regarding a research topic. So far, there are few studies that have examined the efficacy of the science and engineering curriculum in Higher Education Institutions in supporting the entry of undergraduates into the T&C industry after they graduate. Similarly, Lohmann et al. (2009) argued that an exploratory research design is appropriate for investigating research issues that have been barely examined in existing literature. They suggested that such a research design helps to identify new concepts and theories that can form the basis of future studies. Mollick (2014) also suggested that an exploratory research design is useful for establishing initial evidence concerning a research issue. He suggested that this method results in the development of new concepts and theories that enhance the understanding of a given research issue. An exploratory research design is therefore useful for exploring a research issue that has limited coverage in existing literature.

The absence of research hypotheses for my study further reinforces the necessity of an exploratory research design. As the T&C industry was identified by the Task Force on Economic Challenges (2016) of the government as one of the six high-growth economic areas, the Hong Kong government has fully committed to reinforcing the development of the T&C industry in recent years. My study examines the topic of how the science and engineering curriculum in higher education institutions supports undergraduates' entry into the fast-growing T&C industry without basing the research on existing conceptual and theoretical frameworks that define the research issue. The research design thus enabled me to extensively explore the research issue and obtain important information that can be used to establish critical theories and concepts regarding the research issue (Shellenberg et al., 2011).

5.2.2 Data Collection

The data collection process was divided into two phases to address my research questions. In phase one, there were three data sources. The first data source is the cluster units of competency as identified from the Specification of Competency Standards (SCS) of the QF. The universities with a T&C programme constitute the second data source of the study. The third data source is the T&C curricula. In phase two, the views of the T&C stakeholders were collected, making up the fourth data source. Data was collected sequentially from the first three data sources and then the fourth data source.

5.2.3 Data Analysis Approach

Data analysis is the process of systematically searching through and arranging data collected for a study. It involves interpreting and making sense of the accumulated data to increase the understanding of them and to enable the researcher to present the findings (Creswell, 2003). It is critical to select a proper analytical method that can help to interpret the collected information systematically and determine the results accurately. Two data analysis approaches were used.

- Phase one – Content Analysis
- Phase two – Thematic Analysis

5.2.3.1 Content Analysis

In view of the importance of studying and interpreting large and diversified amounts of information from the first three data sources in phase one, a content analysis was the most appropriate choice as an analytical tool. 'Content analysis' has become a sort of umbrella term that refers to an almost boundless array of research approaches and techniques (Hsieh and Shannon, 2005).

Content analysis is a systematic analysis method. It is a method used to reduce long texts into fewer content categories with a particular focus on explicit rules of coding (Krippendorff, 2004). In addition, Pegues (2007) stated that content analysis can be useful for curriculum developers and evaluators in exposing to what extent objectives are represented in a particular text. Krippendorff (2004, p. 138) mentioned the need for a systematic content analysis as a major phase of formative evaluation.

> Although content analysis has been defined in many various ways over the years, it has been perceived as a rigorous form of statistical examination. Being a part to advances in the technology force, content analysis emphasises the term *systematic procedure* as an important aspect. He further expresses that: "The historian, three decades ago, would pick out quotations from newspapers according to his judgment; today, systematic procedures of content analysis for mass communication have developed".

Underlying meanings and ideas are revealed by analysing patterns in the elements of a text, such as words or phrases (Yang, 2008). Texts are empirically coded based on a coding system to make observations about the information conveyed. Yang further indicated that content analysis can refer to a variety of methods of studying and retrieving meaningful information from documents and text, including written text (books and papers) and hypertexts (text found on the internet). As the research methods adopted in the current study involve qualitative and quantitative approaches, it was necessary to explore how content analysis supports the interpretation of qualitative and quantitative data. The aim of the content analysis is to investigate the content of a study carried out in a particular discipline and to understand its development (Apaydın, 2010). For these reasons, content analysis was adopted in phase one of my research study. I carefully considered the notions of trustworthiness and credibility in the content analysis to ensure that the underlying textual and numerical evidence was consistent with the interpretation. In phase one, T&C curricula were analysed with respect to the cluster units of competency from the QF. A qualitative data analysis tool, NVivo in version 12, was used. The T&C curricula from the universities and the cluster units of competency were uploaded separately to NVivo.

5.2.3.1.1 Determining the Unit of Analysis

Krippendorff (2004) defined coding units as ‘units that are distinguished for separate description, transcription, recording, or coding’ (p. 97). Units are wholes that analysts distinguish and treat as independent elements. To generate a meaningful outcome, the counted objects must be distinct. For example, it makes sense to count words or sentences but not an entire text. Meanings are also countable when it is possible to make a distinction among meanings and when one meaning does not depend on another. The coding units are aspects of the text that convey messages to the reader, including complete paragraphs, one or more sentences, questions, figures with captions, tables with captions, pictures with captions and each complete step of an activity. Each of these text parts is referred to as a ‘unit of analysis’ (Chiappetta, Fillman and Sethna, 2004). The following coding units are included in this study for the content analysis:

1. Courses
2. Syllabi

5.2.3.1.2 Coding

The units of analysis in coding the curricula were defined as courses and syllabi. To facilitate interpretation, the cluster units of competency were assigned codes. For instance, Measurement Uncertainty (Chemical Testing) was coded as Q1 and Measurement Uncertainty (Microbiological Testing) was coded as Q2. The codes for the cluster units of competency are summarised in Appendix A. A matrix containing the names of courses and the cluster units of competency was constructed. Each course or subject occupies a row (e.g., A, B, C, … etc.) and each cluster unit of competency occupies a column (e.g., Q1, Q2, Q3, … etc). By counting the number of courses that match with the cluster units of competency in terms of keywords or content, the data was analysed via a quantitative approach. With this, any skill gap between the curricula and the job competency requirements in the T&C industry could be identified.

5.2.3.1.3 Cluster Units of Competency

Clustering is the process of grouping competencies into combinations that have meaning and purpose related to the work functions and needs in an industry or enterprise (Government of Australia, 2009). To meet organisational needs, employers formulate training programmes based on the cluster units of competency with respect to the competencies and qualification levels attained by their employees (HKQF, 2016).

The work nature of the T&C industry can be largely categorised into testing, inspection and certification by the Hong Kong Council for Testing and Certification. To further analyse the activities of the T&C industry to identify its core functional areas and job competency requirements, the cluster units of competency for the T&C industry as outlined by the QF were identified as the first data source in my study. In the SCS developed by the QF in 2015, there are 51 cluster units of competency required for T&C practitioners as shown in Appendix A.

5.2.3.1.4 Science and Engineering Curriculum

The science and engineering curricula in the universities were the second source of data used to address the first research question of the current study. The universities in Hong Kong are divided into two categories: universities funded by the University Grants Committee (UGC) and non-UGC-funded universities. The UGC of Hong Kong is an advisory committee responsible for advising the government of Hong Kong on the development and funding needs of higher education institutions. There are eight UGC-funded universities and one non-UGC university, as shown in Table 5.1.

Table 5.1: The universities in Hong Kong

UGC-funded universities	University A
	University B
	University D
	University E
	University F
	University G
	University H
	University I
Non-UGC-funded university	University C

While identifying the nine universities for my study, the programmes in the following faculties or schools were taken into consideration:

1. Science faculties; or

2. Engineering faculties; or

3. School of science department; or

4. School of engineering department

In addition, it was necessary to determine the programmes related to the T&C discipline. To find the relevant programmes, a search for the keywords *testing* and *certification* in the programme objectives was conducted (Appendix B). The information was obtained from the webpages of the nine universities.

Following the electronic search, a total of 138 programmes from the nine universities were selected for review. Three T&C programmes were identified from three universities – two UGC-funded universities and one non-UGC-funded university – as shown in Table 5.2. The results to identify the relevant keywords *testing* and *certification* in the three programmes are summarised in Appendix C. The three universities and programme names are summarised in Table 5.2.

Table 5.2: Three universities offer T&C programmes

University	**Name of programme**
A	Bachelor of Science (Honours) in Analytical Sciences for Testing and Certification
B	Bachelor of Science (Honours) in Analytical and Testing Sciences
C	Bachelor of Science (Honours) in Testing and Certification

University H and University I offered relevant courses in their faculty of social science and faculty of business, respectively. There was no faculty of science or engineering in either of these universities.

5.2.3.1.5 Testing and Certification Programmes

The corresponding curricula of the three T&C programmes were further reviewed. Information on the curricula was obtained from the webpages of the three universities. The curricula were converted into PDF documents and uploaded to NVivo. With this, a content analysis was conducted and compared with the 51 cluster units of competency from the QF.

5.2.3.2 Thematic Analysis

In phase two, an exploratory research was carried out by conducting interviews to collect data for the study. The data collected were analysed by thematic analysis approach. Interviews enable the researcher to collect information concerning the opinion, beliefs or practices of individuals (Brinkmann, 2014). Interviews can be used to collect information relating to the present or past experiences of the respondents. According to Qu and Dumay (2011), the interview is an integral element of qualitative research studies. However, the use of interviews in research can be problematic, and thus it is important for researchers to be pragmatic when using this method of data collection. Qu and Dumay stressed that there is a danger in assuming that respondents in an interview are moral and competent sources of information. Denzin and Lincoln (2005) further supported the notion that empirical data obtained through interpretive research methods such as interviews are impressionistic, unreliable and lacking objectivity. For this reason, Qu and Dumay (2011) suggested that qualitative research interviews should be carefully planned and adequately prepared for. I believe that note taking and intensive listening are critical elements in an interview. Qu and Dumay further posited that interview methods are grouped into three categories. Structured interviews study facts and adopt a neo-positivist view. Unstructured interviews focus on meaning and adopt a romanticist view towards research. Semi-structured interviews, on the other hand, focus on obtaining the local perspective by examining the social construction of situated accounts. This type of interviews also acts as a bridge between structured and unstructured interviews. This study used semi-structured interviews to collect the data required to answer the research questions.

5.2.3.2.1 Semi-structured interviews

Semi-structured interviews consider the respondent as a pivotal part of the research study process and not an epistemologically passive participant. According to Alvesson (2003), structured and unstructured interviews consider the respondents as a mere source of answers. In contrast, semi-structured interviews adopt a localism perspective and challenge the assumptions made by those who use interviews instrumentally. Alvesson further expressed that semi-structured interviews enable the researcher to use the interview process as a way of examining the meaning of the research issue to the respondent and understanding the subject in order to construct a situated account. The localism approach adopted by semi-structured interviews regards respondents as people who can provide answers to the research questions through interpersonal and complex interactions. This data collection approach is therefore appropriate for me to examine 1) the efficacy and extent to which the current science and engineering curriculum meets the competency standards of the QF and 2) if there is any skills gap that exists between the current science and engineering curriculum and the job competency requirements of the T&C industry.

My study examines the efficacy of the science and engineering curriculum in bridging the gap between industry needs and classroom knowledge in the T&C industry. The primary objective of the research is, therefore, to determine whether the Hong Kong higher education institutions need to revise the science and engineering curriculum to enhance the efficacy of their programmes and ensure that graduates entering the T&C industry have the skills and competencies required to competently work in the industry. To do so, I focused on the experiences of employers in Hong Kong, especially in the T&C industry. In semi-structured interviewing, I used a guide to cover specific research questions. Details are discussed in section 5.2.3.2.2 (Interview Guide Development). The interviewer was responsible for the order in which the interview questions were asked. However, the questions were standardised to ensure that the responses provided by the respondents could be used to answer the research question. Semi-structured interviews enable the researcher to collect detailed information relating to the research topic using a conversational approach to data collection (Rabionet, 2011). Therefore, interviews are appropriate to use in my study as I intend to explore a research issue extensively in order to inform curriculum design.

5.2.3.2.2 Interview Guide Development

An interview guide was developed for the semi-structured interviews based on the method proposed by Erffmeyer and Johnson (2001). In the study, they suggested that the researcher should conduct a pilot interview to uncover critical issues that should be the focus of the interviews. I carried out a pilot interview with one of the respondents in order to develop an interview guide that would help in the realisation of the primary objective of the study. A pilot interview was carried out before the data collection to test the instruments of the research method. As Van Teijlingen and Hundley (2001) suggested, a pilot study is crucial to a good study design; it can help to identify potential practical problems during the research procedure, and it would be useful for assessing the adequacy of the research instruments. A pilot interview with Participant A representing the T&C stakeholder was held on 20 February 2019. The major aim of the interview was to acquire an overview opinion about the extent to which the undergraduate science and engineering curriculum in the Hong Kong higher education institutions facilitates entry into the T&C industry. In the pilot interview, the work readiness and competency of graduates taking science and engineering courses and T&C courses were discussed, which aligned with my research questions. The discussion of the pilot study ensured that the topic of study is significant in terms of research, and that the research method was appropriate for responding to the research questions (Van Teijlingen et al., 2001).

5.2.3.2.3 Significance of the Pilot Interview

The pilot interview with Participant A provided guidance on important interview questions that would offer insights into the research issue. The interview schedule and questions were then fine-tuned based on the research questions and objectives. I ensured that only questions that were relevant to the research topic were retained in the interview guide when conducting the interview for Participants B and C to fulfil the needs of the investigation. After conducting the pilot interview with Participant A, I needed to fine-tune the interview questions. When presenting Question 10 (What do you think about the depth of works and breadth of works? How much depth works best for skill development in the T&C industry?), I observed that Participant A was hesitant to answer this question. After I explained further, she was able to express her expectations of graduates having abilities in ‘depth of work’ and ‘breadth of work’ and comment on science and engineering graduates and T&C graduates in this aspect. To allow the subsequent respondents (Participants B and C) to express their views smoothly and logically, I fine-tuned Question 10 and combined Question 11 as the follow-up question (see Appendix D and Appendix E). With this, I conducted the interview with Participant B and Participant C by using the revised semi-structured interview questions (see Appendix E).

Additionally, I examined existing literature to understand the impact of curriculum on the competencies of graduates. The studies by Holmes (1999), Jaeger (2003) and Kouwenhoven

(2009) provided important insights into the relationship between curriculum and graduate competence. The key findings of these studies were used to develop an interview guide.

The interview guide was divided into four key sections, each with a set of questions seeking to determine if there is any skill gap between competency requirement in the workplace and curriculum design. In total, the interview guide had 12 questions aimed at understanding the competencies of graduates studying the science and engineering programme and the T&C programmes (see Appendix F).

First section – Training

The first section focused on training. This set of questions aimed to determine, from the perspective of the interviewee, whether the training provided in higher education institutes is sufficient and whether any skill gap exists. The objective was to get the interviewees to talk about their own views and expectations regarding training as well as the observations that they have made regarding the ability of university graduates to effectively transition into the workplace and engage in performing their duties.

Second section – Employment

The second section focused on employment. The primary objective of this section was to determine whether the science and engineering curriculum equips graduates with the capability to enter the T&C market such as by meeting the market needs or gaining employment opportunities.

Third section – Competence

The third section focused on T&C workplace competence. The section examined the views of the interviewees regarding the competence of the graduate employees in their organisations. Competence is a key determinant of efficacy of the training programme design. The section explored job-specific competencies of new graduate employees to determine whether they possess the required competencies in T&C from the perspective of employers. The aim was also to determine whether the newly employed possess soft skills that employers require in the contemporary workplace as well as the T&C environment and to compare the competency of graduates studying the science and engineering programme with the T&C programme. Additionally, the section examined how organisational culture has hindered or supported the employees in developing competencies and skills that match organisational needs.

Fourth section – Curriculum

The fourth section of the guide examined the design of the science and engineering curriculum. The aim of this section was to examine whether science and engineering curriculum teaches graduates to be competent in the marketplace, and to investigate the view of employers on the depth of work and breadth of work. Their views were useful for me to further investigate the two modes of curriculum design in the T&C programmes that were observed in my previous study: deep coverage and broad coverage. The section also sought to examine whether the existing science and engineering curriculum aligns with the QF competency standards.

5.2.3.2.4 Sample

The samples used for the study were the middle-level managers of three organisations in the T&C industry. These respondents were selected because they work in the industry and have experience in recruiting science and engineering as well as T&C graduates. The middle-level managers of companies in this industry are in a position to offer insights into the challenges that they experience with such graduates in relation to their ability to meet job demands. These managers interact directly with the fresh graduates and therefore understand their weaknesses as well as their strengths in relation to job-specific competencies and skills.

The three respondents were identified through purposive sampling. According to the findings made by Etikan et al. (2016), it is impossible to use the whole population when conducting research, hence the use of sampling techniques such as purposive sampling. The authors defined purposive sampling as a non-probability sampling method in which the target population is selected based on certain practical criteria. The number of respondents was limited to three and in-depth interviews were conducted.

An exploration of workplace competency among graduates who have studied science, engineering or T&C programmes is essential. Thus, I have identified two criteria for the selection of the respondents. The first criterion was that the respondents should be the decision makers for recruiting technical staff. The second criterion was that the respondents should be at the management level with experience in supervising graduates from science, engineering or T&C programmes. In this regard, the respondents fulfilling the two criteria should have experience in employing the graduates and be able to share their insight on the graduates.

5.2.3.2.5 Participants

Etikan et al. posited that in this type of sampling, the researcher selects a participant that is well informed on the research issue. As the three participants selected for the study employ university graduates from S&E and T&C programmes, I believed that they would have knowledge regarding the competency of the graduates that they employ, their knowledge of work, capabilities, and working attitudes.

I made phone calls and sent emails requesting appointments to address the three participants concerning my research study. The purpose of these appointments was to brief the participants about the research study and to conduct the semi-structured interviews. Consent was received from the respondents for participation in the interview (see Appendix G). The interviews lasted around 45 minutes for each manager and followed the interview schedule (see Appendix H). The portfolios of the three participants are summarised in Table 5.3.

Table 5.3: Profile of the participants

Participant	Position	No. of staff supervised	Department	Working experience
A	Senior Engineering Manager	16	Automotive and Electronics	• 20 years' working experience in reliability engineering • Charter engineer of the Hong Kong Institution of Engineers • Working in government subvention organisation
B	Testing Manager	30	Customer and Retail Services	• 15 years' working experience in multinational testing laboratories • Experienced in electronic testing, physical and mechanical testing.
C	Section Manager	44	Hard-line and Soft-line Section	• 18 years' working experience in multinational testing laboratories • Experienced in chemical testing, physical and mechanical testing.

5.2.3.2.6 Coding

Themes in qualitative research do not just emerge. They have to be identified through a process referred to as coding. According to St. Pierre and Jackson (2014), the logic of coding assumes that words and phrases obtained through interviews can be both data and code. Data in this sense refers to brute words and phrases that are yet to be interpreted for meaning. Code, on the other hand, refers to words that are meaningful. The authors further argued that in order to code data effectively, the researcher must assume that the words and phrases recorded during interviews with respondents are raw data that can be de-contextualised and broken apart through coding. After the coding process is completed, words and phrases are placed into different categories, ultimately resulting in themes to be analysed. Basit (2003) also emphasised the importance of coding in qualitative research studies by arguing that data analysis is the most challenging and important aspect of qualitative studies. He linked the process of coding with the inductive research approach by suggesting that coding is defined by inductive reasoning. Basit further argued that raw data is interesting to look at but cannot help the researcher to understand the study problem unless such data is analysed systematically to reveal key insights regarding the research issue. Coding is the process through which raw data is categorised and subdivided for analysis. Basit posited that coding is not data analysis even though it is a crucial aspect of the data analysis process. He further highlighted that data analysis in qualitative research is not a discrete but rather a continuous process.

Researchers can code data electronically or manually. My study used electronic coding by using the software NVivo 12. The coding process was guided by the method proposed by Thomas (2006). He identified the key themes emerging from the interviews conducted. My study applied the same approach to code data and identify key themes. Through this coding process, key themes under each research question were identified for further analysis.

5.2.3.2.7 Theme Identification

Theme identification was conducted based on the six-stage procedure proposed by Braun and Clarke (2006). The stages are (1) familiarisation with data, (2) categorisation of data through the process of coding, (3) theme identification, (4) a review of potential themes (5) theme definition and naming, and (6) report presentation. An expanded discussion of each stage of the theme identification process is undertaken below.

Step 1: Familiarisation with data

As proposed by Braun and Clarke (2006), the first stage of the data analysis process involves data familiarisation. During this stage, I must get reacquainted with the information collected from the respondents. During this stage, I listened to interview audio recordings and read the transcripts. The interviews were conducted in Chinese, the language that the participants were proficient in, to avoid any misunderstandings during the data collection process. I translated the responses into English during this stage. The interview recordings were listened to several times to ensure accurate translation and transcription. The translation was also done immediately after the interview process to ensure that necessary clarifications were made while the participants were still available to make them. Notes were made in the column next to the data (see Appendices I, J and K). Responses related to the research questions were coded to identify patterns or themes in the data.

Step 2: Developing initial codes

The second stage of the data analysis process is probably the most important. This stage involves the initial step in the development of codes. During this process, I took an inductive approach to ensure that the themes identified could lead to the generation of new theories and concepts. A deductive approach to the coding process would hinder the study from resulting in new insights regarding the research issue. The themes identified were thus driven by data and not the personal preferences of my research. Braun and Clark (2006) referred to codes as the ‘building blocks’ of data analysis because they turn raw data into patterns that can provide important research insights. To ensure that the interview transcripts were recognised successfully by the software NVivo 12 that was used for coding, spreadsheets were prepared to include the transcripts from the three participants with the corresponding interview questions.

The interview transcripts were imported into the software to develop initial codes as shown in Appendix L. At the start of the process, I relied on the findings of the literature review to generate codes. Such an approach was necessary to ensure that I began with the known before moving to the unknown. Additionally, the initial codes were generated based on the research questions developed for the study. The transcripts were coded individually. The coding was done line-by-line to ensure that no line was left without being reviewed for potential codes. I moved to identifying texts that seemed to have meaning and gave them codes. There was no limitation to the number of codes generated at this stage. Some of the meaningful texts identified were assigned more than one code because they seemed to offer information on more than a single issue. The emerging themes were then compared against the research questions to ensure that they were categorised according to the research questions that they answered. The following potential themes were identified in this phase: *training objectives*, *towards market needs, towards employment*, *competitiveness, skills, employment opportunities, education to employability, academic subjects and skill-based subjects, deep* *coverage curriculum design, broad coverage curriculum design, QF competency standard adoption, work readiness, skill mismatch, science/engineering vs T&C graduates.*

Step 3: Theme identification

The third stage of the data analysis process involved the identification of key themes by reading and re-reading the coded nodes on NVivo 12. The initial analysis led to the identification of four key themes. These were *training*, *employment, curriculum* and *competence*. Braun and Clarke (2006, p. 82) posited that theme identification and decision is mainly influenced by the prevalence of particular texts across the transcript. However, I ensured that only the themes related to the study were identified to prevent a loss of focus on the primary study objective. Prevalence of texts or data was considered regarding the number of times participants offered similar views or opinions. The themes and sub-themes were thus identified as shown in Figure 5.4 of Appendix M.

Step 4: A review of potential themes

During the fourth stage of the data analysis process, the themes identified were reviewed and refined. While some themes were discarded because they were duplicates, that is, they focused on similar issues, others were merged because they focused on related issues. The process was informed by the claims made by Braun and Clarke (2006, p. 91) that themes should be distinct, that is, they should clearly focus on different issues. After the process of reviewing and refining themes, they were named and defined. *Training objectives* as a major theme was discarded because there was insufficient data to support it. As a result of this, the four sub-themes identified in the theme of ‘training’ were refined into three sub-themes of *competitiveness, market needs* and *employment readiness* (see Figure 5.5 of Appendix M).

For the sub-themes in ‘curriculum’, *deep coverage curriculum design* and *broad coverage curriculum design* were merged and represented by *curriculum design* (see Figure 5.6 in Appendix M).

Additionally, the four sub-themes identified under the theme of ‘competence’ were refined into three sub-themes and represented by *skills mismatch*, *work readiness* and *QF competency standard adoption* (see Figure 5.7 of Appendix M).

<u>Step 5: Theme definition and naming</u>

The fifth stage of the data analysis process involves the definition and naming of themes identified from the data collected. The definition and naming of the themes identified is achieved by understanding the story that each theme tells (Braun and Clarke, 2006). In this research study, the names of themes were basically a summary of the stories that they told. For instance, the theme of ‘training’ was so named because it talked about whether new science and engineering graduates were properly trained to cope with the demands of the job in the T&C industry. The theme also focused on training requirements regarding new science and engineering graduates seeking employment in the T&C industry. However, a few modifications were required because the themes were not providing what Braun and Clarke (2006, p. 92) defined as a ‘coherent and internally consistent account’. During the modification, some of the sub-themes were renamed (see Figure 5.8 of Appendix M). The transcripts were re-read carefully and cross-checked for the nodes generated by NVivo 12 (see Appendix N). The final thematic map is shown in Figure 5.9 of Appendix M.

<u>Step 6: Producing the report</u>

The final stage involves the presentation of the results obtained from the data analysis process. The themes are effectively analysed to present research findings in a manner that can be understood by the reader. The presentation of study results in a clear and concise manner enhances the validity and trustworthiness of the research findings. Such an approach to data presentation also ensures that the results of the study can be used by various parties that are interested in the report (Braun & Clarke, 2006). The themes and sub-themes identified from the interviews are presented in Table 5.4.

Table 5.4: Themes and sub-themes

Themes	Sub-themes
Training	• Competitiveness • Market needs • Employment readiness
Curriculum	• Employability • Hard skills and soft skills • Curriculum design
Employment	• Market needs • Skills • Employment opportunities
Competence	• Work readiness • Skills mismatch • QF competency standard adoption

After drafting transcripts as well as the analysis of results, I shared the findings with the participants involved to help them get a sense of what I had discovered based on the interviews. These results could also help them revisit their employment and training policies to improve employee productivity. While these were not the final research findings, I believed that it was necessary to share with them some of the key issues that I had identified so far because they had also expressed interest in analysing the outcomes of the study.

5.2.3.2.8 Inter-Relationship of the Themes

The theme of training focuses on how the curriculum can prepare graduates to be competitive in the labour market. Training also examines the skills possessed by graduates and market needs, that is, the extent to which training prepares science or engineering graduates with sufficient employment readiness and high employability to meet the needs and expectations of T&C organisations. The theme of employment, on the other hand, focuses on how the science or engineering curriculum creates employment opportunities for graduates entering the T&C market. Employment opportunities can also be looked at from the perspective of the ability of the curriculum to help graduates become desirable employees based on the existing employment opportunities. The results of the interview also show that the curriculum itself is an important factor to consider when training undergraduates. The curriculum should help graduates to transition from university to the T&C workplace. A curriculum creates international teaching and training test standards and thus ensures that the quality of education and the competencies of graduates are improved within a region, nation or even globally. Additionally, the curriculum should be designed to equip graduates with both soft skills and hard skills. Hard skills are discipline specific and deal with the core skills required to work competently in a particular industry or organisation. Such skills are academically oriented and relate specifically to a career. Soft skills, on the other hand, focus on the skills that are generally required in employment. Finally, the results focus on the theme of competence. The QF competency standard adoption by the employers and its alignment with the curriculum were investigated. Curricula should be designed to enhance the competence of graduates and ensure that they have the skills and capabilities required to deliver effectively in a particular role. Competence not only ensures that the skills possessed by a graduate can provide sufficient work readiness, but also that the skills match what is required by the employer. The competence of an employee determines his or her performance and career success.

5.3 Ethical Considerations

I need to be mindful of the issue of confidentiality because of my dual role as a teacher and a researcher. NCES (2006) suggested that learning institutions should have a policy in place to work within data protection and security. Since phase one of my research study involved the collection of the curricula of the testing and certification programme from my university, it was important that I handled the data carefully and complied with my university's policy. However, there are some general principles that might inform professional judgment about confidentiality. Richards (2016) suggested that information obtained from and about participants during an investigation is confidential unless otherwise agreed in advance.

My role as a senior lecturer teaching material science subjects is closely linked to my chosen area of research and, as such, I cannot stand completely outside the research project, as my own experience and background as a former consultant working in the Hong Kong Productivity Council (HKPC) have shaped who I am today and bring a certain intimacy with the research inquiry. I may also have to discuss with and receive advice about incidents or concerns from my colleagues in the workplace and make decisions regarding the study, factors that could impact the validity and reliability of the research findings. Robins (2003) argued that reflective practice, over time, allows you to become skilful in making informed judgments and professional decisions.

Adhering to established ethical principles is therefore a key consideration for me in conducting phase two of the research study. Ethics are an important element in social research. Guillemin and Gillam (2004) argued that there are two ethical dimensions in research studies. The first dimension of ethics focuses on the procedures involved in the research. Procedural ethics ensure that research studies are conducted according to the established ethical procedures by relevant institutions such as the Institutional Review Board. The procedures guide how the researcher should approach issues relating to informed consent, safety of human subjects, privacy and confidentiality rights, and deception. Guillemin and Gillam identified the second dimension of ethics as ethics in practice that deals with the unpredictable yet often important issues that arise during the research process – for instance, how to handle a situation where the respondent considers a question to be uncomfortable. Ellis (2007), however, introduced a third ethical dimension referred to as relational ethics. The author described this ethical dimension as ethics that recognise and appreciate mutual respect. Ellis posited that the researcher should always be concerned with what he or she should do at a given moment as opposed to what the subject should do (see Appendix G).

To enhance the validity and trustworthiness of the study findings, it is important for the researcher to adhere to qualitative research ethics. Jaap Van (2014) explained that adherence to ethical standards in qualitative research prevents the occurrence of unethical research practices such as the fabrication or falsification of data and therefore enhances the validity and trustworthiness of the research findings. According to Resnik (2011), ethics promote research objectives such as truthfulness and error avoidance. Resnik further argued that ethics are essential for collaborative work because the researcher often collaborates with various parties such as co-researchers and respondents when carrying out a research study. Additionally, ethical norms enhance accountability and increase public support for the research. I obtained consent from the university research ethics committee. By granting the consent to go ahead with the research, the committee acknowledged that the research study meets the established procedural ethics.

I also adhered to the principles of ethical education research as provided by the British Educational Research Association (BERA, 2018). I specifically adhered to the guidelines relating to responsibilities to study participants by ensuring that consent was voluntary and that there was openness and disclosure of all relevant information pertaining to the research. Participants were all required to read and sign the consent form in Appendix G before taking part in the study. I also adhered to ethical principles throughout the research process to ensure that respondents felt respected and valued. I recognised that the respondents were individuals worthy of respect and treated them as such by respecting their opinions and listening to their concerns. Ethical protocols were carefully considered while conducting the semi-structured interview. As provided for in the BERA guidelines, there is a need for the researcher to ensure the privacy of participants (BERA, 2011). The names of the universities were protected by maintaining anonymity throughout the reporting of the research and data was stored securely and confidentially. Data was also anonymised by referring to participants as 'Participants A, B, and C' to conceal their identity and protect them from any victimisation.

<u>Informed consent</u>

A transparent approach was adopted throughout the interviews to promote mutual respect and confidence between the participants and me. I asked straight questions without attempting to manipulate the participants into providing answers that matched the expectations and preferences of my research. Informed consent was gained from the three participants, who gave their permission to be interviewed, as well as have the interview audio recorded. The 'Consent Form for Participation in a Research Study' outlines issues including title of the study, description of the research, risks and discomforts, potential benefits, protection of confidentiality and voluntary participation (see Appendix G). Time was also spent with the participants at the beginning of the interview explaining what the study involved. An interview schedule was established (see Appendix H).

Right to withdraw

It was emphasised to the participants that they had the right to withdraw before, during or after the interview by informing the interviewer either verbally or through writing that they wished to do so. If this request was made, their data would be destroyed and removed from the research.

Debriefing and feedback

Upon completion of the interview, each of the participants was given an opportunity to ask any further questions and given my contact information if they wished to contact me. Additionally, transcripts were sent to the respective participants to collect their feedback. The three participants confirmed that the data were recorded and interpreted correctly.

5.4 Summary

This study employed mixed methods of research, which were divided into two phases incorporating pragmatism and exploratory research design approaches. To investigate how the current science and engineering curriculum facilitates entry into the T&C industry in Hong Kong, I collected and analysed data during the two phases. The data collection sources in phase one included: (1) job requirements for the T&C industry, (2) Qualifications Framework competency standards, and (3) the science and engineering curriculum. By conducting content analysis, I used both qualitative and quantitative approaches to examine whether the higher education science and engineering curriculum produces graduates that have the skills and competencies required in the T&C industry. The findings in this phase were used to establish the next phase, exploratory research study. The semi-structured interview was conducted. I selected three participants who were well informed on the research issue and should have good knowledge in the competency of the graduates. Hence, the three participants selected for the study employed university graduates from S&E programmes and T&C programmes. After collecting data, thematic analysis was conducted by applying Braun and Clarke’s (2006) process consisting of six stages.

CHAPTER SIX: FINDINGS

This chapter presents the findings of both phases of the study with discussions on the findings of each phase. The chapter begins with an examination of phase one findings and then proceeds to the findings from phase two.

6.1 Phase One Findings

There were four main steps conducted in phase one. In order to study the extent to which the current science and engineering curriculum meets the competency standards of the Qualifications Framework (QF) for the T&C industry, 51 key competencies (see Appendix A) in the QF were identified in Step 1. In Step 2, the faculties of science and engineering of the eight universities in Hong Kong were reviewed to determine whether any testing and certification programmes were established. It was found that three testing and certification programmes have been developed by three universities – University A, University B and University C as shown in Table 6.1.

Table 6.1: Name of testing and certification programmes

Universities	Name of Programme
A	Bachelor of Science (Honours) in Analytical Science for Testing and Certification
B	Bachelor of Science (Honours) in Analytical and Testing Sciences
C	Bachelor of Science (Honours) in Testing and Certification

The curricula of the three universities were further analysed by identifying any courses/syllabi that complied with the QF competency requirements by conducting Step 3 and Step 4.

- Step 3: The curricula and corresponding credits of the testing and certification programmes at University A, University B and University C were identified.
- Step 4: With the courses obtained from Step 3, a mapping exercise was conducted to identify the common features between the courses and the QF competency requirements.

The units of analysis for coding the curricula are courses and syllabi. To facilitate interpretation, the cluster units of competency were assigned codes. For instance, Measurement Uncertainty (Chemical Testing) was coded as Q1 and Measurement Uncertainty (Microbiological Testing) was coded as Q2. To visualise the data for the analysis, a matrix containing the names of courses and the cluster units of competency was constructed as shown in Appendix O.

The data were analysed via a quantitative approach wherein the number of courses that matched with the cluster units of competency in terms of keywords or content was counted as shown in Appendix F, enabling the identification of any skill gaps between the curricula and the job competency requirements in the T&C industry.

For the purpose of analysing the three testing and certification programmes, the course titles and course objectives were uploaded to NVivo, and matching words corresponding to the 51 cluster units of competency were revealed. The results are presented by word frequency. Subsequently, the frequency distribution for the courses corresponding to the cluster units of competency was further analysed. The following two conditions demonstrate the identification of keywords via a content analysis.

6.1.1 Condition 1: Fully Matching Keywords

As an example, for the course 'Quality Management and Laboratory Accreditation' for the Bachelor of Science (Honours) in the Analytical Sciences Testing and Certification programme at University A, the course title and objectives are tabulated as follows:

Table 6.2 Fully Matching Keywords

Course title	Course objectives	Keywords	Matching cluster unit of competency and code
Quality Management and Laboratory Accreditation	To provide students with comprehensive knowledge of the fundamentals of quality management and its application to testing laboratories in developing a management system for quality assurance, administrative and technical operations, as well as to introduce the accreditation of laboratory management systems in conformity with international standards.	'testing' 'quality' 'assurance'	Testing Quality Assurance (Q44)

The keywords 'testing', 'quality' and 'assurance' were identified from the course title and course objectives and match exactly with the keywords in one of the cluster units of competency: Testing Quality Assurance (code no: Q44). Hence, the course 'Quality Management and Laboratory Accreditation' includes the competency of 'Testing Quality Assurance'.

6.1.2 Condition 2: Partial Matching of Keywords

Some courses include cluster units of competency through partial matches with the keywords. For example, referring to the course 'General Laboratory Techniques and Safety' in the Bachelor of Science (Honours) in Analytical Sciences Testing and Certification programme at University A**,** the course title and course objectives are defined as follows:

Table 6.3 Partial Matching of Keywords

Course title	**Course objectives**	**Keywords**	**Matching cluster unit of competency and code**
General <u>Laboratory</u> Techniques and Safety	To introduce the basic techniques commonly used in <u>biological</u> and chemical experimental studies, as well as the safety practices in <u>biological</u> and chemical <u>laboratories</u>	'laboratory' 'laboratories' 'biological'	1) Basic Laboratory Preparation Work (Q6) 2) Basic Microbiological Laboratory Preparation Work (Q7)

The keywords 'laboratory', 'laboratories' and 'biological' match with two cluster units of competency: Basic Laboratory Preparation Work (code: Q6) and Basic Microbiological Laboratory Preparation Work (code: Q7).

The findings for the UC courses were examined and data analysis was organised according to three aspects:

1. Number of UC courses (section 7.2)
2. Coverage of codes (section 7.3)
3. Weighting of codes (section 7.4)

6.1.3 Findings – Number of UC courses

The frequency distribution of UC courses and codes for the three universities were tabulated in Appendix P, Appendix Q and Appendix R, respectively. The number of UC courses was studied and compared for the three universities.

- University A – Bachelor of Science (Honours) in Analytical Sciences for Testing and Certification
- University B – Bachelor of Science (Honours) in Analytical and Testing Science
- University C – Bachelor of Science (Honours) in Testing and Certification

Table 6.4 Number of UC courses matched with cluster units of competency of QF

University	No. of courses	No. of UC courses	Percentage of UC courses
A	136	42	31%
B	48	12	25%
C	42	20	48%

For University A, 42 out of 136 courses (31%) wewe matched with cluster units of competency. The remaining 94 courses (69%) are not related to any cluster units of competency, so no code is included. Similarly, for University B, 12 out of 48 courses (25%) are related to the cluster units of competency. For University C, 20 out of 42 courses (48%) are related to the cluster units of competency. Remarkably, for all three programmes, fewer than half of the courses are identified as UC courses. This finding was of particular importance to my study. The finding shows that the universities courses offered do not meet the needs and expectations of the T&C industry with regard to employability skills and graduates competencies. The graduates may not, therefore, not possess the employability skills and graduates competencies required for them to work effectively in T&C industry.

Information revealed from the percentages of UC courses was used to determine the coverage of codes by the UC courses, which has implications for the extent of the curriculum that meets the specifications of competency standards of QF for the T&C industry. The distribution of the number of UC courses with the number of codes is illustrated in Figures 6.1a, 6.1b and 6.1c.

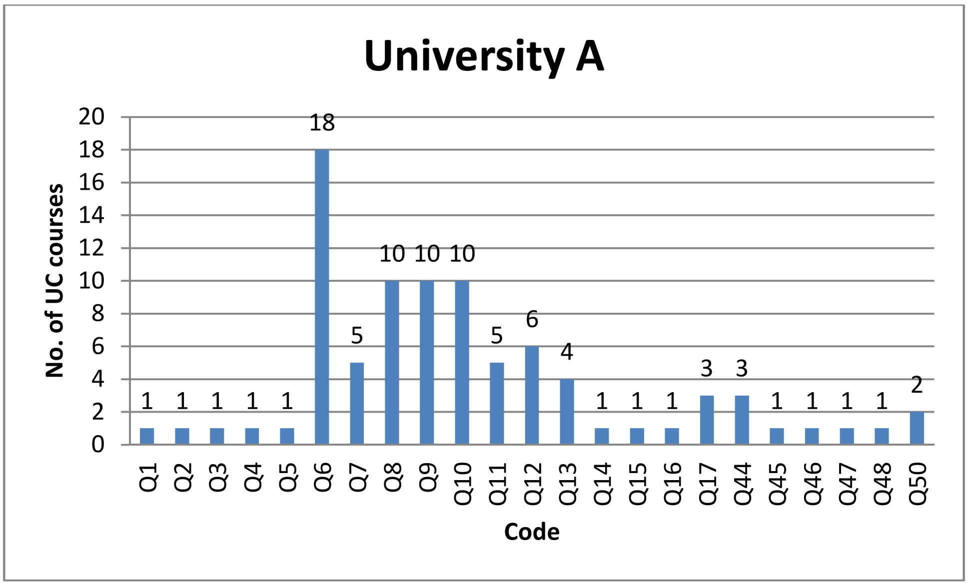

Figure 6.1a: No. of UC courses for University A

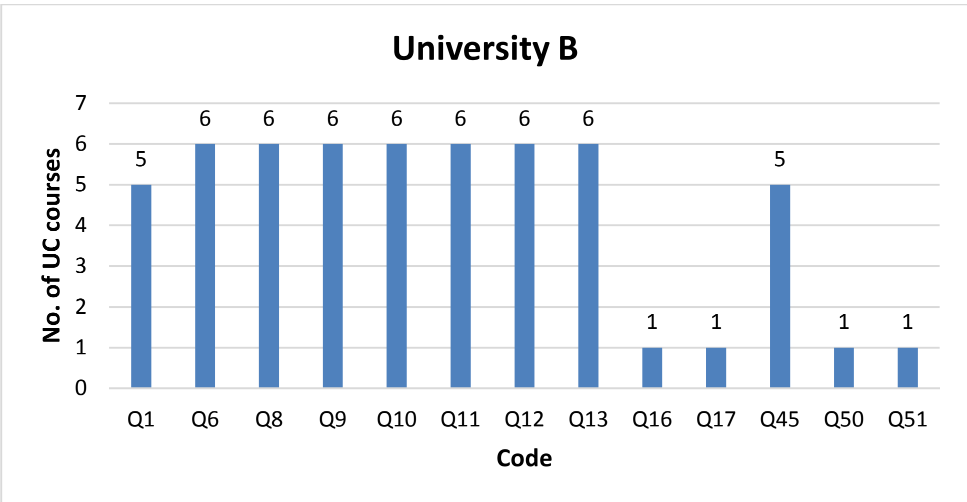

Figure 6.1b: No. of UC courses for University B

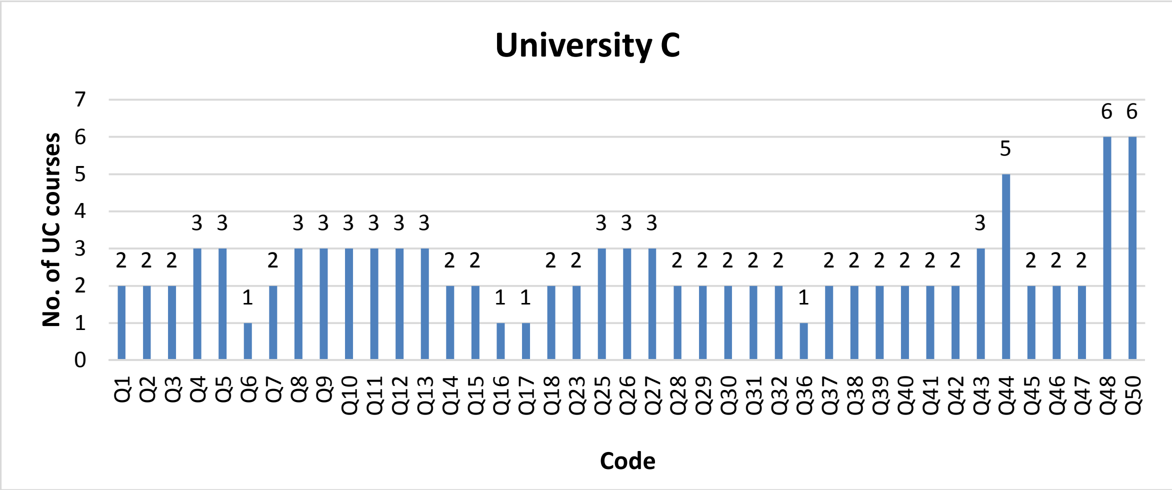

Figure 6.1c: No. of UC courses for University C

6.1.4 Findings – Coverage of Codes

The number of codes included by the UC courses is worthy of investigation. The level of coverage can further indicate the extent to which the programmes meet the competency requirements for T&C according to Figure 6.2.

- For University A, 23 codes are mentioned in the course descriptions.
- For University B, 13 codes are mentioned in the course descriptions.
- For University C, 41 codes are mentioned in the course descriptions.

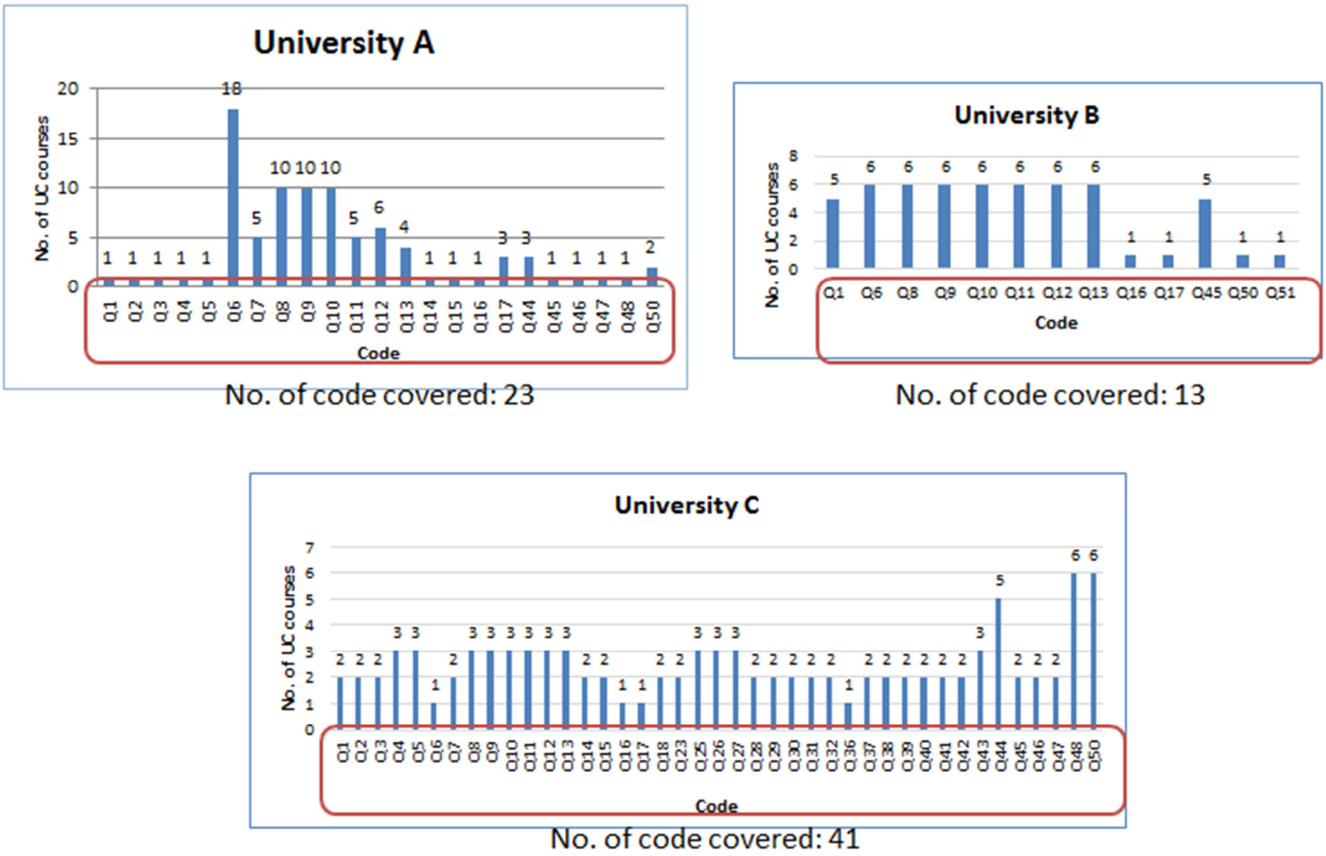

Figure 6.2: Coverage of codes for the three universities

The degree of code coverage can be calculated by using the following equation:

$$\%\ \textbf{of code covered by UC courses} = \frac{\textbf{No. of codes covered by UC courses}}{\textbf{Total number of codes}}$$

Table 6.5: Percentage of codes covered by UC courses

University	**No. of codes covered by UC courses**	**Percentage of codes covered by UC courses**
A	23	45%
B	13	25%
C	41	80%

As the total number of codes of QF was 51, by using the above equation, the percentages of codes covered by the UC courses were calculated as shown in Table 6.5. The results indicate coverage of less than 50% for codes at Universities A and B. This finding shows that the coverage of the curricula of the current testing and certification programmes may not meet the competency standards of the QF for the T&C industry. The findings imply that universities do not cover courses broadly and this limits the extent of industry-specific knowledge that students can acquire. While deep coverage might enable students to understand key concepts better, the lack of broad coverage means that they will not get the opportunity to learn many important concepts that can enhance their employability skill and graduate competencies.

6.1.5 Findings – Weighting of Codes

Regarding the degree of code coverage, the UC courses of the three programmes cannot provide full coverage of codes. The degree of code coverage only describes the number of codes covered by the UC courses. I argue that the degree of code coverage does not indicate the importance of a code. Schwartz (2008) previously raised a similar concern. He expressed that one of the most contentious conflicts in science education concerns the optimal degree of content coverage in science courses. Frequently simplified into the opposing camps of 'depth versus breadth', the distinction serves to characterise two separate and competing philosophies about which almost all educators hold passionate opinions. The two factors are highly concerned with programme design. Jeffrey (2017) supported a similar view. He indicated that the key learning outcomes desired for a college student are driven by both depth and breadth. Questions designed with better understanding of depth and breadth in experiential learning could have far-reaching implications for program design, structure of general education requirements, advising practices and overall student success.

There is a need to examine the weighting of codes covered by the UC courses for the three programmes. Weights serve as scaling factors to specify the depth of code coverage and to indicate the relative importance of codes.

University A

As mentioned in section 6.1.4, the UC courses contain 23 codes. Some codes refer to more than one UC course. For example, the code Q50 relates to the courses 'Inspection and Certification' and 'Principles of Quality Assurance' as shown in Appendix P. It is noted that Q6, Q8, Q9 and Q10 are the most highly emphasised codes that relate to the UC courses.

Since courses are offered on a credit basis, the depth of code coverage can be interpreted by studying the frequency distribution in terms of credits earned (Figure 6.3). Each course offers three credits. The number of credits for the courses are summarised in Appendix P.

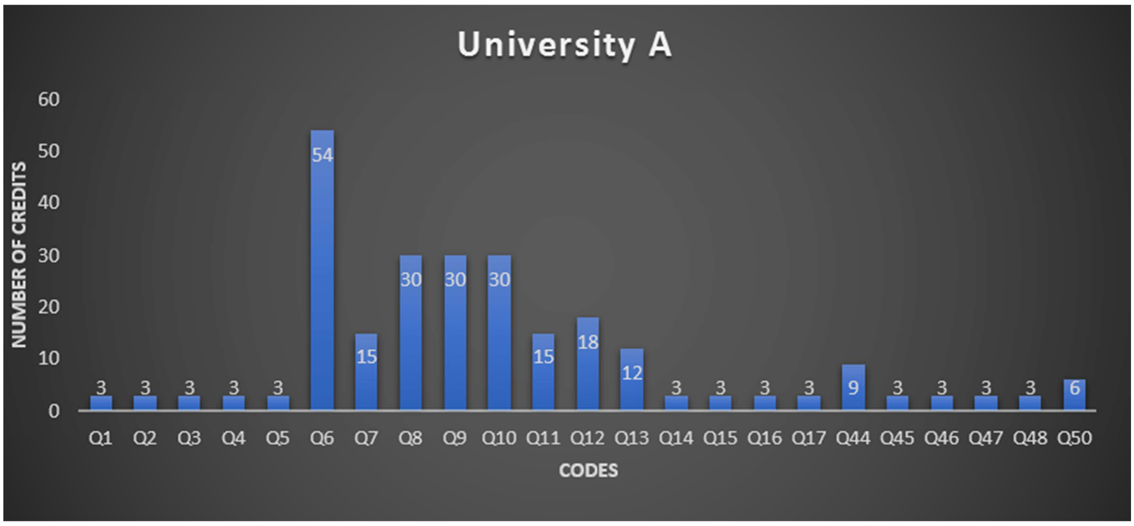

Figure 6.3: Frequency distribution of credits earned in the codes for University A

Over 50% of credits earned through the UC courses are related to the codes Q6, Q8, Q9 and Q10 as shown in Table 6.6. The four emphasised codes are closely related to chemical testing.

Table 6.6 Credit earned through UC courses related to emphasised codes for University A

	Emphasised code		
Code	Cluster units of competency	Credits earned	Percentage of credit (n=258)
Q6	Basic Laboratory Preparation Work	54	21%
Q8	Chemical Testing (Elemental Analysis)	30	12%
Q9	Chemical Testing (Elemental Analysis – Atomic Spectrometric Techniques)	30	12%
Q10	Chemical Testing (Elemental Analysis – Inductively Coupled Plasma Spectroscopic Techniques)	30	12%
Total			**57%**

The programme is led by the Department of Applied Biology and Chemical Technology. The objective of the programme is to train students to perform chemical analysis in commercial and government laboratories. Students are expected to learn about laboratory preparation and analytical techniques, including Atomic Spectrometric techniques and Inductively Coupled Plasma Spectroscopic techniques, as well as complete various courses related to chemistry disciplines. This explains the number of UC courses closely related to the codes Q6, Q8, Q9 and Q10.

University B

According to Figure 6.4, there are 13 codes related to UC courses. The codes and their corresponding courses are summarised in Appendix Q.

Like University A, some codes refer to more than one UC course and each course carries three credits. The frequency distribution of the credits earned in the codes is presented in Figure 6.4.

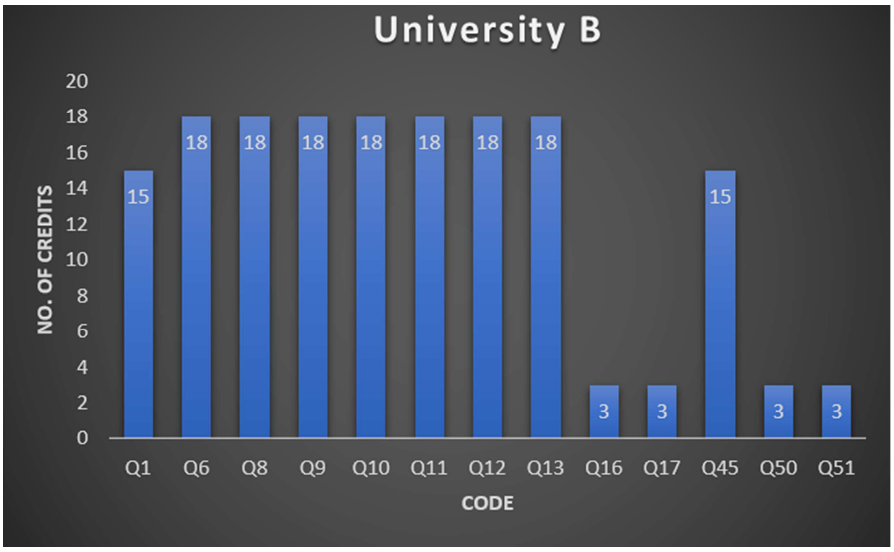

Figure 6.4: Frequency distribution of credits earned in the codes for University B

Regarding Table 6.7, most of the UC courses are included in the seven codes Q6, Q8, Q9, Q10, Q11, Q12 and Q13. These seven codes cover approximately 85% of the credits. It is notable that the emphasised codes are related to chemical testing and chemical analysis. It is also observed that Q8, Q9, Q10, Q11, Q12 and Q13 have the following common courses:

- Analytical Chemistry & Testing Science Tutorial I
- Chemistry Laboratory for Analytical Testing Science
- Analytical Chemistry & Testing Science Tutorial II
- Materials Testing & Characterisation
- Spectroscopic Techniques for Structure Determination
- Dissertation in Analytical & Testing Sciences

This implies that students are expected to learn about analytical chemistry and analytical testing science as well as materials science and testing in this programme.

Table 6.7 Credit earned through UC courses related to emphasised codes for University B

	Emphasised code		
Code	**Cluster units of competency**	**Credits earned**	**Percentage of credits (n=168)**
Q6	Basic Laboratory Preparation Work	18	11%
Q8	Chemical Testing (Elemental Analysis)	18	11%
Q9	Chemical Testing (Elemental Analysis – Atomic Spectrometric Techniques)	18	11%
Q10	Chemical Testing (Elemental Analysis – Inductively Coupled Plasma Spectroscopic Techniques)	18	11%
Q11	Chemical Testing (Organic Analysis)	18	11%
Q12	Chemical Testing (Organic Analysis – Chromatographic Technologies)	18	11%
Q13	Chemical Testing (Organic Analysis – Molecular Spectrometric Techniques)	18	11%
Total			**77%**

The programme is led by the Department of Chemistry. The objective of the programme is to provide students with a solid knowledge base and skills in the variety of techniques that are used to solve diverse problems in analytical chemistry and testing science. This also explains the number of UC courses closely related to analytical chemistry.

University C

This is a four-year programme totalling 42 courses. According to Table 6.4, 20 out of 42 courses (48%) are related to the cluster units of competency. The remaining 22 courses (52%) are not related to any cluster units of competency, so no code is included. Therefore, nearly half of the courses are identified as UC courses. Each course carries three credits. Figure 6.5 shows the frequency distribution of codes containing the number of credits. A broad range of codes is covered. Codes Q44, Q48 and Q50 contain the greatest number of credits relative to the other codes.

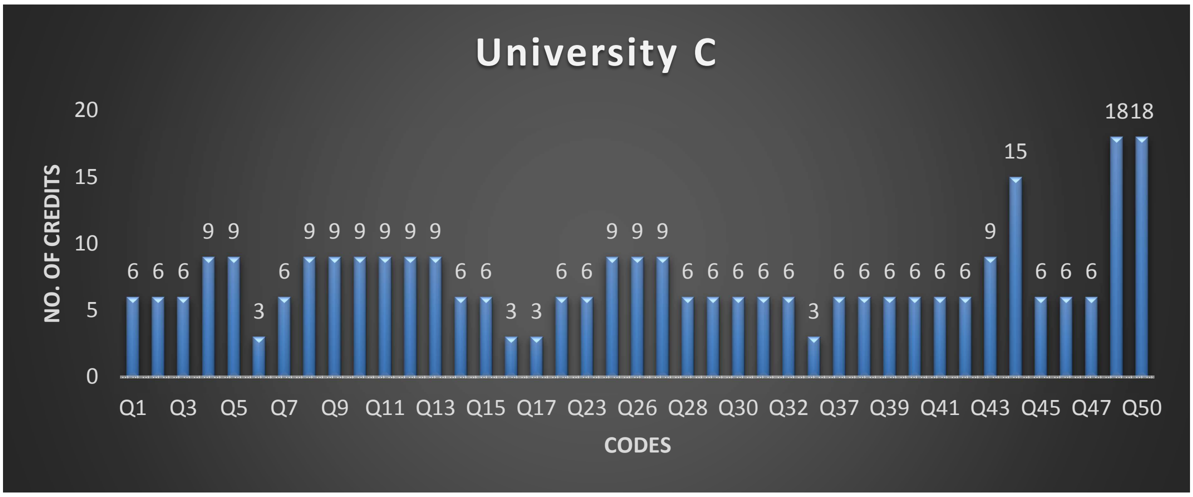

Figure 6.5 : Frequency distribution of credits earned in the codes for University C

It is worthwhile to further analyse the codes Q44, Q48 and Q50 with their related UC courses. These three codes relate to five common UC courses:

- Principle of Production Design & Manufacturing Process Management
- Quality Management for Science & Technology
- Conformity Assessment & Laboratory Accreditation
- Safety & Reliability for Science & Technology
- Audit, Inspection & Certification

Table 6.8: Credits earned through UC courses related to emphasised codes for University C

	Emphasised code		
Code	**Cluster units of competency**	**Credits earned**	**Percentage of credit (n=303)**
Q44	Testing Quality Assurance	15	5%
Q48	Inspection of Consumer Products	18	6%
Q50	Quality Assurance of Inspection Operations	18	6%
Total			**17%**

The competencies of codes Q44, Q48 and Q50 emphasise quality management and manufacturing process management. Students are expected to realise the relationship between laboratory management and quality assurance as well as between production and quality assurance. This is aligned to the objectives of the programme in that it aims to train students in a broad range of skills for career opportunities including testing specialist, production supervisor and quality controller.

It is worthwhile to note that these three emphasised codes had a relatively lower number of credits than those of Universities A and B, less than 10% of credits earned per individual code according to Table 6.8. A wide coverage spectrum is observed without significant and emphasised codes.

To understand the characteristics of the three university programmes, a combined frequency distribution for the three universities is illustrated in Figure 6.6 and Table 6.9.

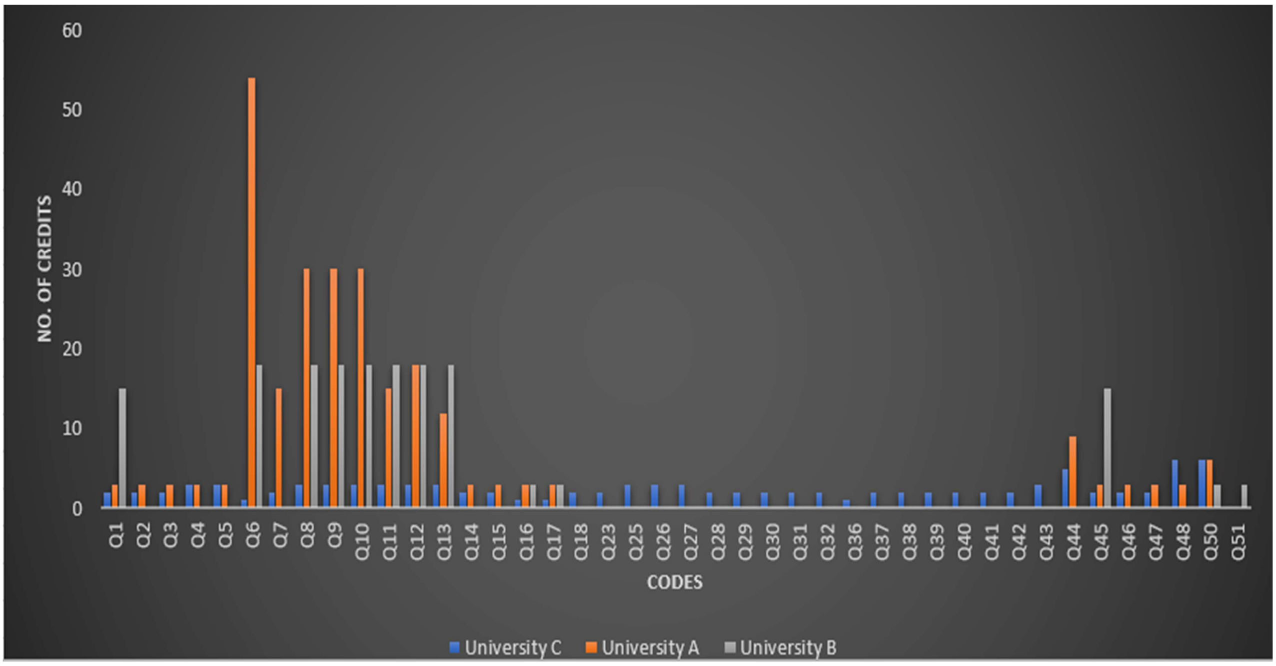

Figure 6.6: Combined frequency distribution chart for Universities A, B and C

Table 6.9: Results on the coverage of the codes and the weighting of emphasised codes

<table>
<tr><th>University</th><th colspan="2">Coverage of codes</th><th colspan="2">Weighting of emphasised codes</th></tr>
<tr><td>A</td><td>45%</td><td rowspan="2"><50%</td><td>57%</td><td rowspan="2">>50%</td></tr>
<tr><td>B</td><td>25%</td><td>77%</td></tr>
<tr><td>C</td><td>80%</td><td>>50%</td><td>17%</td><td><50%</td></tr>
</table>

Based on the above results, the characteristics of programme design for University A was similar to those of B. This was examined by the coverage of codes and the weighting of emphasised codes. The coverage of codes is less than 50% but the weighting of emphasised codes is more pronounced, whereas the codes in University C are highly covered but the emphasised codes are not significantly found. The results on the coverage of codes and the emphasised codes are summarized in Table 6.9. Hence, the similarities and differences are interpreted in Table 6.10.

Table 6.10: Comparisons of code coverage by Universities A, B and C

Similarities
1. In Universities A and B, Q6, Q8, Q9, Q10, Q11, Q12 and Q13 are the most common and most emphasised codes related to chemical testing.
2. Universities A and B do not cover most of the codes. The coverage of codes is less than 50% (45% for University A and 25% for University B).
Differences
1. There is no emphasised code for University C as compared with Universities A and B. Fewer credits are obtained from any individual code.
2. University C covers most of the codes as compared with Universities A and B. A broad range of codes is covered (80% of coverage).

The results above indicate that there is an inverse relationship between coverage of codes and weighting of codes. The higher the coverage, the lower the weighting, whereas the lower the coverage, the higher the weighting. The weighting for low coverage shows that the depth of learning is more important than the scope of material covered. More in-depth learning enables graduates to have skills and competencies that match those required in the work environment.

In a similar vein, Schwartz (2008) elaborated on a noteworthy aspect regarding his views on full coverage and deep coverage. He pointed out that one extreme is emphasised on 'full coverage' or 'breadth', the view that students are best served by encountering a great number of topics relevant to a particular science discipline. He further elaborated that there is an alternate view which is typified by the term 'deep coverage' or simply 'depth'. Considering these opposing views, the characteristic code coverage can be observed for Universities A, B and C according to Table 6.9 and Table 6.10. Based on these findings, I give the following analysis.

- Universities A and B have emphasised codes covering more UC courses and credits. Students spend more time studying the emphasised codes in depth. Hence, deep coverage of UC courses is demonstrated at Universities A and B.
- At University C, no obvious emphasised code is identified but a wide coverage of codes is observed. Therefore, breadth of coverage of UC courses is exhibited at University C.
- Hence, I interpreted the situation by using a light spectrum as shown in Figure 6.7. The two extreme colours, blue and red, represent deep coverage and broad coverage, respectively. Universities A and B both approach deep coverage, whereas University C approaches broad coverage.

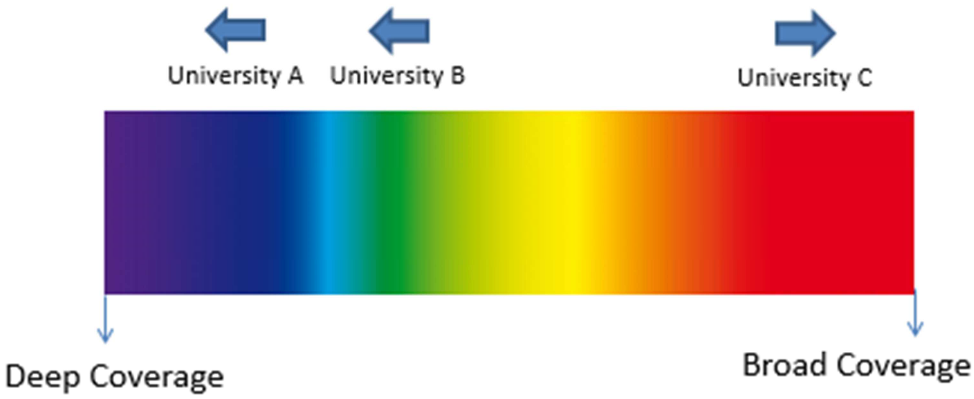

Figure 6.7: Spectrum of code coverage

6.1.6 Discussion of Phase One Findings

The findings of the study show that more in-depth learning enables graduates to have skills and competencies that match those required in the work environment. The depth of learning is, therefore, more important than the scope of material covered. These findings indicate that there is a need to ensure that the curriculum designed enhances the ability of students to grasp topic concepts and develop skills and competencies required in the workplace. Without such a curriculum, Hong Kong Universities will be producing graduates that are not able to apply classroom concepts in the workplace. Schwartz (2008) elaborated on a noteworthy aspect regarding his views on full coverage and deep coverage. He pointed out that one extreme is emphasised on 'full coverage' or 'breadth', the view that students are best served by encountering a great number of topics relevant to a particular science discipline. He further elaborated that there is an alternate view which is typified by the term 'deep coverage' or simply 'depth'. Based on these arguments and the findings of this study, there is a need to ensure that there is broad coverage of topics while emphasizing on depth. These elements should be combined to ensure that graduates are highly competent due to vast and in-depth knowledge. Emphasising only on one element, depth or breadth, would limit the ability of Hong Kong graduates to work competently in the testing and certification sector. While universities A & B focus on deep coverage, university C emphasizes on broad coverage. None of the three universities produces science and engineering graduates that are competent enough to work in the T&C industry, an indication that a combination of deep and broad coverage would result in more competent and skilled graduates.

Taken together, the breadth versus depth issue gives a possible linkage to my research question regarding the extent to which the curriculum meets the competency standards required for the T&C industry. According to Coker and Porter (2015), increased breadth of learning leads to increased career development benefits, employability, a greater likelihood of altering students’ future plans, and other gains. Hence, broad coverage of courses seems to be more effective at increasing the extent to which the curriculum meets the competency standards for the T&C industry. Therefore, the impact on deep and broad coverage of curriculum design in relation to employability skills and graduate competencies was addressed in the investigation in phase two of my study.

6.2 Phase Two Findings

Following a detailed coding process to identify key themes emerging from the responses provided by the study participants (see the transcripts in Appendix T, Appendix U and Appendix V), four themes were identified including training, curriculum, employment and competence.

Theme 1: Training

The data demonstrate that the existing science and engineering curriculum is technically relevant to the jobs in the T&C industry. According to Participant A,

> ***'I think that the subjects they learn in science/engineering programmes are relevant to our jobs and ready to work in technical field'. (A3)***

Participant C also made similar claims by stating that

> ***'To be considered for the position of engineer, applicants must hold a degree with a major in science or engineering (S&E) subjects such as physics, product engineering'. (C2)***

The responses indicate that the current science and engineering curriculum is relevant to the jobs in T&C industry. In other words, the curriculum supports the training of science and engineering students to work in the T&C industry. While the responses do not demonstrate the efficacy of the curriculum in this regard, they nevertheless shows that the curriculum was designed with the intention of training science and engineering students to work in the T&C industry.

Participant B stated that the majority of recruited graduates were targeted to science and engineering disciplines. This indicates that the science and engineering curriculum is relevant to the jobs in T&C industry.

‘The minimum requirement is a diploma from a higher education institution in science/engineering, electrons engineering/mechanical engineering or a testing discipline, with no work experience required. That means we welcome fresh graduates to apply to our posts. Four years ago, the majority of our graduates studied science/engineering’. (B1)

However, the current science and engineering curriculum does not train and equip graduates sufficiently with the qualifications and competencies expected of employees in the T&C industry. According to Participant B,

‘Science/engineering graduates demonstrate strength in understanding theory and knowledge and can therefore understand the principles of tests. However, they are poor at conducting tests practically and require a long time to learn the testing instruments. They are also weak in the concepts of quality assurance and quality control’. (B2)

Since the science and engineering curriculum aims to train graduates in a technical field, the training may not particularly help students entering T&C industry. Participant B states that

‘In recent years, we have received more applications from fresh graduates studying testing and certification and fewer applications from science/engineering graduates. The reason is that electronic/mechanical graduates look for jobs at construction firms and electronics companies. Thus, around 90% of our graduates studied testing and certification’. (B1)

This response shows that while the curriculum enables science and engineering students to develop some skills that are required in the T&C industry, it does not effectively help graduates to have the competencies and qualifications required to work in the T&C industry.

These concerns are also shared by Participant A who claims that science and engineering graduates are not sufficiently qualified and competent based on the Qualifications Framework of the T&C industry. The respondent states that they are unable to competently perform specific tasks that are central to the operations of the organisation and which determine its ability to meet its goals and objectives in the market. The respondent states that

> ***'As the graduate was strong in physics, he quickly learned how to operate analytical instruments such as scanning electron microscopes and x-ray inspection. However, he had difficulty understanding the test standards. He even incorrectly interpreted the test procedures and produced inaccurate test results'. (A3)***

The response suggests that science and engineering students are not trained properly based on the qualifications and competence expectations of the T&C industry. Similar claims are made by Participant C who states that

> ***'When recent graduates conduct the tests, they are closely monitored by their supervisors to avoid errors. Because recent graduates lack experience, they seldom meet my expectations'. (C2).***

The response provided by Participant C implies that organisations that employ science and engineering graduates in the T&C industry might have to make arrangements to ensure that the new employees are constantly supervised to minimise errors and safeguard the reputation of the firm. Additionally, the response demonstrates that T&C must develop effective policies to transition new employees into more serious roles to mitigate errors. Participant A also identifies the importance of ensuring that graduates are well-prepared to meet market needs by stating that

‘We also have customers from the area of manufacturing and product design. We provide variety of service to ensure we have sufficient competitiveness. Hence, they are not simply looking for testing’. (A2)

The response shows that they function to meet the needs and expectations of customers. Evidence from the data, therefore, shows that science and engineering students are not trained properly based on the qualifications and competence expectations of the T&C industry.

Theme 2: Curriculum

The study investigated whether the existing curriculum effectively prepare science and engineering graduates for the T&C industry. T&C is a highly competitive industry and the testing laboratories are competing based on turn-around service times and productivity. Testing laboratories who are capable of providing a high variety of test services would be more competitive. Participant A indicates her preference in ‘breadth of work’.

‘Personally, I prefer to have staff capable of providing “breadth of work” because I can fully utilise the manpower resources to carry out more tasks’. (A10)

The response shows that the S&E curriculum as currently designed does not effectively prepare science and engineering graduates to work in the T&C industry because the curriculum was not aimed to align with QF competency standards. The response indicates that these graduates are limited in the scope of jobs that they can perform due to a lack of the necessary skills and competencies required to effectively work in the industry. While the curriculum trains students, it does not equip them with sufficient skills required to work in a highly competitive industry such as the T&C industry. Redesigning the curriculum would enhance its ability to produce graduates who are capable of meeting the employment competencies and skills required in the T&C industry. Participant C raises similar concerns by stating that

> ***'However, S&E and T&C graduates have insufficient knowledge in of these topics. Once again, their knowledge of laboratory management and quality management should be strengthened'. (C11)***

Based on the response provided by Participant C, the current curriculum fails to effectively prepare S&E graduates for the workplace because QF competency standards are not included in the syllabi. There is a need to redesign the curriculum to ensure that it produces graduates that are competent enough to work in the industry. Participant B also states that

> ***'If graduates are capable of providing breadth of work, they could easily find employment opportunities. I could assign different tasks to them. Personally, I have significant flexibility in terms of manpower allocation'. (B10)***

According to Participant B, the current curriculum limits the ability of science and engineering graduates to effectively work in the industry. The participant states that

> ***'If graduates are capable of providing depth of work, they have fewer opportunities to work in other tasks and may not identify their interests'. (B10)***

The response shows that science and engineering graduates lack the hard skills required to work competently in the industry. Hard skills are the technical skills required to perform a particular job effectively. Due to their limitations with regard to competence, they are less employable in the industry compared to T&C graduates. Participant A summarises this aspect by stating that

> ***'Regarding T&C graduates, they have knowledge in various testing methods. We do not need to spend much time training them'. (A11)***

The response shows that employers in the industry prefer T&C graduates over science and engineering graduates due to differences in competence. The study, therefore, determined that the existing curriculum does not effectively prepare science and engineering graduates for the T&C industry.

Regarding the curriculum design, I sent the information on the science and engineering curriculum, T&C curriculum and QF competency standards to the respondents prior conducting the interview. The responses showed that redesigning the curriculum would enhance the competence of graduates and enable science and engineering graduates to competently work in the T&C industry. Participant A states that

> ***'For S&E graduates, they should have training in test standards to ensure that they have a good understanding of test procedures'. (A12)***

The response indicates that redesigning the curriculum would enhance the employability of science and engineering students by ensuring that they meet the qualification and competence criteria of the T&C industry. The results show that the current curriculum does not support the transition of science and engineering graduates into the T&C industry. Science and engineering students are unlikely to meet the established qualification and competency criteria.

Theme 3: Employment

The interviews also revealed that the employment of science and engineering graduates in the T&C industry is a major theme. The curriculum does not enhance their employability due to lack of qualifications and competencies as established in the Qualifications Framework. Participant A states that

> ***'I think that fresh science/engineering graduates understand basic testing concepts. However, they have little knowledge of testing standards, no***

solid experience, and no familiarity with how the tests are performed. Therefore, we employ science/engineering graduates who possess at least two years of working experience in a related field. They take up junior posts as engineering officers'. (A4)

The response shows that fresh science and engineering graduates would find it difficult to secure employment in the T&C industry because the curriculum does not equip them with the skills and competencies required to effectively work in the industry. The requirement of a 2-year working experience demonstrates that fresh T&C graduates would find it much easier to secure employment in the industry compared to science and engineering graduates because they have qualifications and competencies that match the needs and qualifications requirements of the industry.

Participant C makes it even more clear by suggesting that S&E graduates are simply not employable in the industry because they lack the skills and competencies required to effectively work in T&C organisations. The participant states that

'S&E graduates often lack knowledge of and experience with laboratory management, specifically equipment maintenance and calibration, and the ISO 17025 quality system, which is something I assumed they would learn at university'. (C4)

The response indicates that S&E graduates are not employable in the industry and that there is a need to design a curriculum that equips them with the skills and competencies expected of employees in the T&C industry.

Participant B also suggests that science and engineering graduates do not have the skills and competencies required to secure employment in the industry. The participant states that

'Since S&E graduates are weak in conducting tests practically, they cannot skilfully handle testing instruments and require a long time to

> ***learn them. Thus, S\E graduates may not be equipped well to enter the T&C market'. (B4)***

The response provided by Participant B further demonstrates that the current curriculum for science and engineering students does not help them to transition to the workplace environment. They lack the skills and competencies that would enable them to perform well as employees. The results indicate that science and engineering graduates lack the skills and competencies required to secure employment in the T&C industry.

Theme 4: Competence

Competence is also a key theme that determines the efficacy of a curriculum in producing graduates that meet workplace requirements. The study, therefore, sought to determine whether the current curriculum enables science and engineering graduates to be competent employees in the T&C industry. Participant A states that

> ***'Compared to science and engineering graduates, T&C graduates demonstrate high skills and abilities in testing'. (A5)***

The response provided by Participant A shows that science and engineering graduates lack key competencies required to effectively work in the industry. The response also implies that the current curriculum has deficiencies with regard to ensuring that engineering and science graduates can work competently in the T&C industry. Similar concerns are shared by Participant C who states that

> ***'S&E graduates perform better than T&C graduates in exploring and developing new test methods, but recent S&E graduates have lower productivity. Consequently, S&E graduates with at least two years' experience working in testing labs are preferred to recent graduates'. (C5)***

The response provided by the participant implies that unless T&C organisations develop programmes to bridge the skills gap that is common among S&E graduates, the graduates cannot competently work in the industry especially when they are newly graduated.

Participant B also claims that they tend to prefer T&C graduates over science and engineering graduates because T&C graduates are more competent. The participant states that

> ***'We expect fresh graduates to be well-equipped and ready to work without requiring a long training period. That is why we recruit more T&C graduates'. (B5)***

The response shows that science and engineering graduates are less competent and must, therefore, be trained to enhance their ability to competently work in the organisation. They lack work readiness due to due to the inability of the curriculum to prepare them effectively for the workplace. Most employers must allocate resources to the training of science and engineering graduates to make them more competent and able to work in the industry. The need for additional training shows that many of these graduates enter the job market when they are not work-ready.

Testing has been identified as a problem area that many science and engineering graduates lack skills and competencies in. Participant A states that

> ***'Compared to science and engineering graduates, T&C graduates demonstrate high skills and abilities in testing'. (A5)***

The response shows that a skills gap exists with regard to testing since the ability of employees to conduct tests on products is a core job competency requirement in the T&C industry. Participant C also shares these concerns by stating that

> ***'S&E graduates perform better than T&C graduates in exploring and developing new test methods, but recent S&E graduates have lower***

productivity. Consequently, S&E graduates with at least two years' experience working in testing labs are preferred to recent graduates'. (C5)

The response implies that a major skills gap exists among S&E graduates that are joining the T&C industry. Unless additional training is provided, the graduates cannot work competently in the industry.

Participant B also provides more insights into the skills gap that exists between the skills possessed by science and engineering graduates and those required in the T&C industry. The participant states that

> ***'Science/engineering graduates demonstrate strength in understanding theory and knowledge and can therefore understand the principles of tests. However, they are poor at conducting tests practically and require a long time to learn the testing instruments. They are also weak in the concepts of quality assurance and quality control'. (B2)***

The response further confirms that a significant skills gap exists with regard to testing. Most science and engineering graduates are not competent in testing products and this significantly hinders their ability to effectively work in the industry. The claims made by Participant B also show that the skills gap is caused by a curriculum that places more emphasis on theoretical learning than practical. Science and engineering students understand theory but cannot apply much of it in practice.

Due to the market demands, the Electromagnetic Compatibility Test (EMC) is essential for product compliance. The science and engineering graduates and T&C graduates had insufficient knowledge in this new area. Participant A indicates that graduates with knowledge in EMC would be highly considered.

> ***'Therefore, our engineering officers should have knowledge in electromagnetic compatibility (EMC) testing and reliability testing'. (A2)***

Participant B also recommends strengthening the training in EMC testing and reliability testing for science or engineering as well as T&C undergraduates in higher education institutes.

> ***'Electromagnetic compatibility (EMC) testing is vital for product compliance. However, I have observed that both S&E graduates and T&C graduates do not have much knowledge and are weak in this area, including the working principles and the test requirements. Hence, I would highly suggest increasing the coverage and strengthening undergraduates' knowledge of EMC testing'. (B11)***

6.2.1 Discussion of Phase Two Findings

The findings of the study imply that there is a need to redesign the conventional science and engineering (S&E) curriculum to ensure that S&E graduates possess the skills required to competently work in the T&C industry. Regarding training, the results show that the higher education science and engineering curriculum is relevant to the jobs in the T&C industry because graduates were ready to perform technical jobs in the industry. However, the science and engineering curriculum did not train and equip graduates sufficiently for entering the T&C industry. These findings imply that there is a gap between the training that students receive while in school and the expectations of the work environment. As a result, science and engineering graduates cannot work competently in the testing and certification industry. Concerning the curriculum, the study finds that the science and engineering curriculum did not equip graduates with sufficient skills to work in the competitive T&C industry. However, the recently developed testing and certification programmes in the science and engineering curriculum of three universities in Hong Kong were designed to support the transition of T&C graduates from the classroom to the T&C workplace. In a comparison of T&C graduates with conventional science and engineering graduates, the T&C graduates appeared to have better employability skills and graduate competencies needed for work in the industry. The results show that T&C programmes are aligned with QF competency standards. Moreover, the results also indicate that fresh science and engineering graduates would find it difficult to secure employment in the T&C industry compared to T&C graduates. The results further show that S&E graduates were not ready to support ‘breadth of work’ effectively. No matter S&E or T&C graduates, ‘breadth of work’ is the essential factor for graduates to gain the employability in T&C industry. While T&C graduates are weak in concepts and theories, they have skills and competencies required to conduct various tests. Additionally, testing is a problem area for science and engineering graduates.

CHAPTER SEVEN: DISCUSSION OF THE OVERALL RESEARCH STUDY

While the purpose of a curriculum is mainly to facilitate effective learning and not to prepare students for employment, Jon (2008) argued that a curriculum must have the ability to produce graduates that meet the competency and qualifications standards of the industry within which they expect to work. Additionally, Amue Gonewa (2014) claimed that qualified and competent employees can help to drive the competitiveness objectives of contemporary organisations. Based on the study findings, four key themes associated with the ability of the existing curriculum to produce graduates who are qualified and competent in relation to the qualifications and competency expectations of the T&C industry have been identified. These themes are examined below.

7.1 Training

Training was identified as a key theme that focuses on the ability of the current curriculum to produce graduates who have the qualifications and competencies expected of employees in the T&C industry. The results of the study indicate that science and engineering students are not trained properly based on the qualification and competency expectations of the T&C industry. These findings reflect the main concerns of the Hong Kong Council for Testing and Certification (2014) when it identified the three core functions of the T&C industry. One of the key functions of the industry is testing. Graduates applying to work in the industry must, therefore, have the ability to conduct tests competently. According to the Hong Kong Council for Testing and Certification (2014), any graduate who does not possess this skill cannot work effectively in the T&C industry. A claim made by Employer A shows that many graduates lacked key qualifications and competence based on the Qualifications Framework of the industry. The implication is that the science and engineering curriculum does not align with QF competency standards, and therefore does not aim to train graduates in a manner that equips them with the necessary employability skills and graduate competencies required to work in the T&C industry.

7.2 Curriculum

Curriculum was identified as a second key theme that focuses on the ability of the current curriculum to equip graduates with the skills and competencies required to work in a particular industry. Based on the findings, three issues were addressed including curriculum redesign, breadth and depth of course coverage.

7.2.1 Curriculum Redesign

The results of the study show the importance of redesigning the curriculum. Malcolm, Mcinnis and Hartley (2010) emphasised the need for curriculum redesign in science and engineering by arguing that technology and science are dynamic and constantly changing fields. There is a need to regularly review the curriculum to ensure that it is equipping graduates with the skills and competencies required to work in a particular industry.

While the results of this study show that hard skills are essential in the T&C industry, the research study does not provide insights into the ability of the engineering and science curriculum to equip graduates with soft skills such as decision-making skills, analytical skills and critical thinking skills. The employers also failed to mention the importance of these skills to their operations in the market. Heckman and Kautz (2012) argued that there is hard evidence soft skills are just as important as hard skills. Employees with both soft and hard skills are more competitive in the labour market compared to employees who only possess hard skills. Watts (2016) also argued that soft skills significantly determine the ability of a graduate to secure employment in any industry. Failure to recognise these skills as an important part of recruitment and selection criteria shows that many employers in the T&C

industry only focus on the hard skills of graduates, a factor that limits the ability of employees to help an organisation achieve a sustainable competitive advantage in the market. The research study shows that there is a need for the T&C industry to also review its Qualifications Framework to ensure that the graduates hired meet the needs and expectations of the contemporary labour market.

7.2.2 Breadth and Depth of Course Coverage

The study's key findings provide insights into why science and engineering graduates in Hong Kong do not have the skills and competencies to effectively work in the T&C industry. The findings show that more in-depth learning enables graduates to have skills and competencies that match those required in the work environment. The depth of learning is, therefore, more important than the scope of material covered. However, the breadth of coverage is also important even though focusing on breadth alone would not result in competent graduates. Schwartz (2008) emphasised the importance of 'full coverage' or 'breadth' by arguing that students are best served by encountering a great number of topics relevant to a particular science discipline. The results of the study imply that it is essential to focus on both breadth and depth of coverage. While universities A and B focus on deep coverage, university C emphasises broad coverage. None of the three universities produces science and engineering graduates who are competent enough to work in the T&C industry, an indication that a combination of deep and broad coverage would result in more competent and skilled graduates. There is a need to ensure that there is broad coverage of topics while emphasising depth. These elements should be combined to ensure that graduates are highly competent due to vast and in-depth knowledge. A redesign of the curriculum should thus consider how deep and broad coverage can be achieved to produce graduates who are skilled and competent.

7.3 Employment

Employment is also a major theme based on the results of the study. The Qualification Framework of the T&C industry determines whether graduates can secure employment in the industry.

7.3.1 Employability

The results of the research study, however, indicate that science and engineering graduates lack the skills and competencies required to secure employment in the T&C industry. According to Barnett (2003) and Watts (2016), the skills and qualifications of graduates determine their employability. These skills should respond to market needs. As argued by Malcolm, Mcinnis and Hartley (2010), the employability of science and technology graduates is determined by their ability to work in a changing technology industry. The curriculum should, therefore, be designed to ensure that graduates can easily secure employment in the T&C industry. The claims support the findings made by Barnett (2003) and Watts (2016) that individuals become employable when they possess the skills and qualifications required to work in a particular organisation or industry. Without these skills, individuals become less employable since most employers only hire candidates that can help them meet their market needs.

The results imply that the current curriculum makes science and engineering graduates less employable in the T&C industry as compared to T&C graduates. Science and engineering graduates can only become more employable in the industry when the curriculum is redesigned to match their skills and qualifications with those expected by employers in the T&C industry.

7.3.2 Employment Readiness

While science and engineering graduates may possess superior theoretical knowledge compared to graduates who have only been trained in T&C, they are not able to effectively translate this knowledge into practice. Science and engineering graduates lack employment readiness compared to students trained in T&C. These results support the findings of the Hong Kong Economic Report published in 2016, which concluded that there is a challenge with regard to the ability of the curriculum to train students effectively and produce graduates who are ready for the job market. As a result, many graduates take up jobs that require lower qualifications or find it difficult to secure employment.

7.3.3 Work Readiness

The study also identified curriculum as a key issue in the training of science and engineering graduates. The design of a curriculum significantly determines the quality of graduates that it produces. According to Weert (2011), a curriculum should support the transition of graduates from the classroom to the workplace. Additionally, the curriculum should ensure that graduates meet the qualification and competency requirements of the industries for which they hope to work.

The results determine that the existing curriculum does not effectively prepare science and engineering graduates for the T&C industry. These findings support the claims made by Stuckey (2013), which are that most higher education science and engineering curricula do not equip students with practical skills, and this lowers their employability. As demonstrated by the responses provided by the employers, they would prefer T&C graduates because they possess the practical skills required to work in the industry. While science and engineering students consider career paths in the T&C industry, the curriculum does not help them meet the qualification and competence requirements of the industry. Doggan and Gotta (2007) argued that the inability of higher institutions to produce graduates with the qualifications and competencies required to work in their industries of choice originates from the fact that these institutions are not compelled, either by law or regulation, to produce graduates that meet the qualification and competency standards of the industry in which they aim to find employment. As a result of this, many of the graduates produced have theoretical knowledge but are unable to apply this knowledge in practice.

7.4 Competence

Another theme identified from the study is competence. The results of this study support the findings contained in the Hong Kong Economic Report published in 2016, which showed that there is a need to improve the ability of graduates to competently perform in the workplace. The results of this study also support Khir's finding (2006) that most graduates lack the technical know-how to competently perform in the work environment. Similar findings were made by Pitan Oluyomi and Adedeji (2012), Carroll and Tani (2013), and World Economic Forum (2014). Their findings suggested that the mismatch between the skills of graduates and those required in the workplace contributes to the incompetence of most graduates. The research study shows that the current curriculum has resulted in a mismatch between the skills of science and engineering graduates and the skills required of employees in the T&C industry. The curriculum should be redesigned to ensure that it produces graduates who are ready to enter the job market and can work competently within the T&C industry.

A key finding arising from the evidence of this study demonstrates that the current curriculum for engineering and science students in institutions of higher learning does not help graduates meet the qualification and competency expectations of the T&C industry.

7.4.1 Competitiveness

The science and engineering curriculum needs to be improved to ensure that the training that students receive prepares them for employment in T&C industry. Based on the results of this study, the current curriculum does not meet the needs and expectations of the market in terms of the qualifications and competencies of employees. The Qualifications Framework for the T&C industry revolves around market needs and thus graduates who possess the skills and competencies stipulated in the framework are better positioned to help organisations in the industry to meet their market objectives.

According to Piccoli et al. (2009), business organisations must meet the needs and expectations of clients to remain competitive in the market. To enhance their competitiveness, organisations must hire graduates with the qualifications and competencies required to meet the needs and expectations of clients. Amue Gonewa (2014) claimed that employees who are qualified and competent can increase the competitive advantage of an organisation. The current science and engineering curriculum does not produce graduates that can help T&C organisations effectively compete in the market. As a result of this, science and engineering graduates are less competitive in the T&C job market compared to T&C graduates. Organisations that want to outperform competitors would be more likely to employ T&C graduates than science and engineering graduates.

7.4.2 Skills Gap

In accordance with my research question, it is important to determine whether a skills gap exists with regard to job competency requirements of the T&C industry. The Hong Kong Council for Testing and Certification (2014) identifies testing, inspection and certification as core job competency requirements of the T&C industry. Graduates seeking employment in the industry must, therefore, have competencies in testing.

The research findings determine that graduates lack competency in testing, which confirms the notion that a skills gap exists since the ability of employees to conduct tests on products is a core job competency requirement in the T&C industry. The results support the findings made by Pitan Oluyomi and Adedeji (2012), Carroll and Tani (2013) and WEF (2014), which are that most graduates lack the skills required to competently work in various industries. In parallel, the Hong Kong Council for Testing and Certification (2014) has reported a lack of a formal professional status for people working in the T&C industry. The committee members of the Hong Kong Council for Testing and Certification interviewed various stakeholders and found a skills gap between academic qualifications and job competencies required by the T&C industry. Hence, my study shows that the skills gap is caused by a curriculum that places more emphasis on theoretical learning than practical understanding. Science and engineering students understand theory but cannot apply much of it in practice. According to Malcolm, Mcinnis and Hartley (2010), a science and technology curriculum can only produce competent graduates when it enables them to develop skills that enhance their ability to meet the needs and expectations of the work environment. The current curriculum has resulted in a skills gap because it does not focus on practical learning and at the same time fails to match the skills of graduates with market requirements.

Analysis of evidence from this study provides information regarding job competency requirements of the T&C industry and the existing curriculum of science and engineering. A skill gap mainly exists in the area of hard skills – testing – an indication that most graduates are unable to apply their knowledge practically.

CHAPTER EIGHT: CONCLUSION AND RECOMMENDATIONS

This chapter concludes the study based on the evidence gathered in response to the research questions. The chapter also provides recommendations for various stakeholders that can be applied to enhance the skills and competencies of Hong Kong graduates entering the T&C industry. The limitations of this research are also examined in this chapter.

8.1 Conclusion

The aim of the study was to determine whether the current higher education science and engineering curriculum supports undergraduates to enter the Hong Kong T&C industry. The study had two key objectives that it aimed to achieve based on the research questions. The first research question was to determine whether the science and engineering curriculum matches the qualification and competency expectations of the T&C industry. The second question sought to determine whether a skills gap exists with regard to job competency expectations of the industry.

Evidence from this study indicates that the current curriculum for engineering and science in higher education institutions does not help graduates meet the qualification and competency expectations of the T&C industry. Most science and engineering graduates lack core graduate competencies that would enhance their employability in the industry. T&C graduates, on the other hand, have the employability skills and graduate competencies required to work in the industry, an indication that their curriculum is designed to support the transition of graduates from the classroom to the workplace. The study further determines that a skills gap exists between graduate competency requirements of the T&C industry and the existing curriculum of science and engineering. Evidence from the study shows that the gap mainly exists in the implementation of testing, an indication that most graduates are unable to apply their knowledge practically.

The study also determines that deep and broad coverage are key elements that influence the competence of science and engineering graduates. A combination of deep and broad coverage would result in more competent and skilled graduates. There is a need to ensure that there is broad coverage of topics while emphasising depth to reduce the gap between work environment expectations and graduate competencies.

Overall, the study determines that Hong Kong must improve its higher education science and engineering curriculum if it is to produce graduates who have the skills and competencies required to effectively perform in the T&C sector.

8.2 Recommendations

Based on the evidence obtained from the study findings, there is a need for education policymakers in Hong Kong to collaborate with other stakeholders such as educators and employers to design a new science and engineering curriculum that would ensure that graduates have the competencies and skills required to work efficiently in the T&C industry upon graduation. The curriculum should reflect the changing needs of the industry as well as the overall strategic economic direction of Hong Kong.

For employers, the study recommends training and development programmes to help science and engineering graduates develop the skills and competencies required to effectively perform in the T&C industry. Employers in the sector can also offer internship programmes to help bridge the experience and knowledge gap and improve the competencies of graduates.

For scholars, further research should be conducted to investigate how to bridge the skills gap between the current science and engineering curriculum and the job requirements of the T&C industry. Although my research study does not provide insights into the ability of the science and engineering curriculum to equip graduates with soft skills such as analytical skills, my findings indicate that employees with both soft and hard skills are more competitive in the T&C market compared to employees who only possess hard skills. Hence, consideration on the types of skills will be investigated in my future study.

There is some limitation in my research. A major limitation of the study is that it uses only three respondents to examine the research issue. The small sample size limits the reliability and validity of the study findings. However, the negative effect of this limitation on the usability of the study findings is mitigated by the sampling technique. The use of purposive sampling ensured that the respondents selected for the study have expert knowledge and are likely to provide useful and valid information.

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Appendix A

Codes of the Cluster Units of Competency

Code	Cluster Units of Competency
Q1	Measurement Uncertainty (Chemical Testing)
Q2	Measurement Uncertainty (Microbiological Testing)
Q3	Measurement Uncertainty (Physical Testing)
Q4	Sample Handling
Q5	Sampling and Sample Handling
Q6	Basic Laboratory Preparation Work
Q7	Basic Microbiological Laboratory Preparation Work
Q8	Chemical Testing (Elemental Analysis)
Q9	Chemical Testing (Elemental Analysis – Atomic Spectrometric Techniques)
Q10	Chemical Testing (Elemental Analysis – Inductively Coupled Plasma Spectroscopic Techniques)
Q11	Chemical Testing (Organic Analysis)
Q12	Chemical Testing (Organic Analysis – Chromatographic Techniques)
Q13	Chemical Testing (Organic Analysis – Molecular Spectrometric Techniques)
Q14	Biological / Microbiological Testing Preparation
Q15	Biological / Microbiological Testing
Q16	Environmental Testing (Microbiological)
Q17	Environmental Testing (Physical)
Q18	Physical and Mechanical Testing (On-Site Concrete Sampling and Testing)
Q19	Physical and Mechanical Testing (Concrete and Its Constituent Materials)
Q20	Physical and Mechanical Testing (Mortar and Grout)
Q21	Physical and Mechanical Testing (Soil and Rock)
Q22	Physical and Mechanical Testing (Bituminous Materials)
Q23	Physical and Mechanical Testing (Basic Structural Diagnostic Tests on Concrete Structures)
Q24	Chemical Testing on Construction Materials
Q25	Physical and Mechanical Testing (Toys and Hardlines – Flammability Tests)
Q26	Physical and Mechanical Testing (Toys and Hardlines – Stability and Construction)
Q27	Physical and Mechanical Testing (Toys – Acoustic Measurement)
Q28	Fabric Construction Tests (Textiles and Garment Products)
Q29	Fabric Strength and Performance Tests (Textiles and Garment Products)
Q30	Care Performance Tests (Textiles and Garment Products)
Q31	Colour-Fastness Tests (Textiles and Garment Products)
Q32	Flammability Tests (Textiles and Garment Products)
Q33	Fibre Analysis (Textiles and Garment Products)
Q34	Garment Trim Tests (Textiles and Garment Products)
Q35	Feather and Down Analysis
Q36	Performance Tests (Footwear)

Q37	Electrical and Electronic Safety Testing (Electric Shock and Energy Hazard Tests)
Q38	Electrical and Electronic Safety Testing (Electrical Insulation Tests)
Q39	Electrical and Electronic Safety Testing (Electrical Products – Construction Evaluation)
Q40	Electrical and Electronic Safety Testing (Thermal Hazard and Flammability Tests)
Q41	Electrical and Electronic Safety Testing (Stability and Mechanical Tests)
Q42	Physical and Mechanical Testing (Electrical Products – Acoustic Measurement)
Q43	Electrical and Electronic Testing (Energy Efficiency)
Q44	Testing Quality Assurance
Q45	Measurement Traceability (Chemical Testing)
Q46	Measurement Traceability (Microbiological Testing)
Q47	Measurement Traceability (Physical Testing)
Q48	Inspection of Consumer Products
Q49	Inspection of Waterworks Products
Q50	Quality Assurance of Inspection Operations
Q51	Occupational Safety and Health

Appendix B

Review summary on the testing and certification programmes in the nine universities of Hong Kong

	Name of Universities	Any Testing and Certification Program	Name of Program
1	**University A**		
	Faculty of Applied Science and Textiles	Yes	Bachelor of Science (Honours) in Analytical Sciences for Testing and Certification
2	**University B**		
	Faculty of Science	Yes	Bachelor of Science (Honours) in Analytical and Testing Sciences
3	**University C**		
	School of Science and Technology	Yes	Bachelor of Science (Honours) in Testing and Certification
4	**University D**		
	Faculty of Science	No	
	Faculty of Engineering	No	
5	**University E**		
	College of Science and Engineering	No	
6	**University F**		
	School of Science	No	
	School of Engineering	No	
7	**University G**		
	Faculty of Science	No	
	Faculty of Engineering	No	
8	**University H**		
	No Faculty of Science or Engineering		
9	**University I**		
	No Faculty of Science or Engineering		

Appendix C

Key words identified in the three T&C programmes of University A, B and C

University A

Bachelor of Science (Honours) in Analytical Sciences for Testing and Certification

Programme Objectives

This programme aims to produce well-trained and competent professionals for chemical analysis as well as accreditation officers, which are currently in strong demand in the local <u>testing and certification</u> industry including commercial and Government laboratories, plus the quality assurance / control units of any manufacturing organizations and professional assessor for accreditation and <u>certification</u> bodies. Through studying this articulation programme, the graduates (applicants are holders of Associate Degree / Higher Diploma in science disciplines) will acquire the knowledge and techniques of up-to-date chemical sciences and allied disciplines plus the essential management skills pertaining to <u>testing and certification</u> industry in order to be professional executives.

University B

Bachelor of Science (Honours) in Analytical Science and Testing Science

Programme Objectives

This area of Concentration Studies aims to help students acquire professional knowledge and technical skills of the <u>testing</u> industry and better prepare them for advanced studies and career development. In the strong collaboration with the Hong Kong <u>testing</u> industry, industrial training and internships are provided for students. Distinctive features include:

- Emphasising professional training and the development of students' analytical and problem-solving abilities;
- Training in the scientific and technological techniques and knowledge to test the safety and quality of products;
- Combining classroom, laboratory and professional experience to enhance students' competitiveness in this expanding industry;
- Gaining practical exposure in field visits, study tours, and summer internship programmes.

University C

Bachelor of Science (Honours) in Testing and Certification

Programme Objectives

The aims of the programme are to provide students with analytical, technical, theoretical and practical knowledge in aspects of testing science; and equip them to play a key role in the industry of testing science. Graduates will acquire a broad knowledge of the concepts, techniques, and tools in testing science and certification. Graduates will find career opportunities in a broad range of testing and certification industries. Typical positions include testing specialist, testing technician, production supervisors, quality controller, merchandiser, etc. Graduates would also be qualified for further study in testing science, applied sciences or related areas in any tertiary institutions in Hong Kong and elsewhere

Appendix D
Pilot interview questions

	Pilot interview questions
1)	What are the entry requirements to apply the technical posts in your company?
2)	What are the duties of the jobs? Do they meet your expectation?
3)	What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?
4)	In terms of work readiness, has the science and engineering graduates in the higher education institutions are well-equipped to enter the T&C industry (such as meeting the market needs or gain employment opportunities)? If not, how the the higher education institution can bridge the gap?
5)	What are your views regarding the competence of new graduate employees studying Science or Engineering programme and Testing and Certification programme in your organisation?
6)	What are some of the job-specific competencies that you think the new employees of i) Science or engineering graduates; and ii) T&C graduates are lacking?
7)	What do you think is the extent of skills gap among the graduate employees?
8)	How has the organisational culture hindered or supported the employees from developing competencies and skills that match organisational needs?
9)	What are your views regarding the alignment of curriculum with QF competency standards for T&C industry? How do think about the coverage of QF competency standards in the curriculum in higher education institutes?
10)	What do you think of the depth of work and the breadth of work? How much depth works best for skill development in the T&C industry?
11)	How do you comment on the depth of works and breadth of works for i) Science or engineering graduates; and ii) T&C graduates?
12)	What are your views regarding the curriculum design for i) Science or engineering graduates; and ii) T&C graduates?

Before revised

Appendix E
Revised interview questions

	Revised interview questions
1.	What are the entry requirements to apply the technical posts in your company?
2.	What are the duties of the jobs? Do they meet your expectation?
3.	What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?
4.	In terms of work readiness, has the science and engineering graduates in the higher education institutions are well-equipped to enter the T&C industry (such as meeting the market needs or gain employment opportunities)? If not, how the the higher education institution can bridge the gap?
5.	What are your views regarding the competence of new graduate employees studying Science or Engineering programme and Testing and Certification programme in your organisation?
6.	What are some of the job-specific competencies that you think the new employees of i) Science or engineering graduates; and ii) T&C graduates are lacking?
7.	What do you think is the extent of skills gap among the graduate employees?
8.	How has the organisational culture hindered or supported the employees from developing competencies and skills that match organisational needs?
9.	What are your views regarding the alignment of curriculum with QF competency standards for T&C industry? How do think about the coverage of QF competency standards in the curriculum in higher education institutes?
10.	What do you think of the depth of work and the breadth of work in the T&C industry? (Follow up questions) How do you comment on the depth of works and breadth of works for i) Science or engineering graduates; and ii) T&C graduates?
11.	What are your views regarding the curriculum design for i) Science or engineering graduates; and ii) T&C graduates?

After revised

Appendix F
Interview Guide

Section	Research Question	Question no	Semi-structured interview questions
Training	Q1	1.	What are the entry requirements to apply the technical posts in your company?
	Q1	2.	What are the duties of the jobs? Do they meet your expectation?
	Q1	3.	What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?
Employment	Q1+Q2	4.	In terms of work readiness, has the science and engineering graduates in the higher education institutions are well-equipped to enter the T&C industry (such as meeting the market needs or gain employment opportunities)? If not, how the the higher education institution can bridge the gap?
Competence	Q2	5.	What are your views regarding the competence of new graduate employees studying Science or Engineering programme and Testing and Certification programme in your organisation?
	Q2	6.	What are some of the job-specific competencies that you think the new employees of i) Science or engineering graduates; and ii) T&C graduates are lacking?
	Q2	7.	What do you think is the extent of skills gap among the graduate employees?
	Q2	8.	How has the organisational culture hindered or supported the employees from developing competencies and skills that match organisational needs?
Curriculum	Q1	9.	What are your views regarding the alignment of curriculum with QF competency standards for T&C industry? How do think about the coverage of QF competency standards in the curriculum in higher education institutes?
	Q1+Q2	10.	What do you think of the depth of work and the breadth of work? How much depth works best for skill development in the T&C industry?
	Q1+Q2	11.	How do you comment on the depth of works and breadth of works for i) Science or engineering graduates; and ii) T&C graduates?
	Q1+Q2	12.	What are your views regarding the curriculum design for i) Science or engineering graduates; and ii) T&C graduates?

Appendix G

Consent Form

Consent Form for Participation in a Research Study

Title of Study: An investigation into how the science and engineering curriculum in higher education institutions supports undergraduates to enter the testing and certification industry in Hong Kong upon graduation

Description of the research

You are invited to take part in a research study conducted by Ms. Fanny Tang from the Nottingham Trent University. The aim of this study is to how the science and engineering curriculum in higher education institutions supports undergraduates to enter the testing and certification industry in Hong Kong upon graduation. Your participation will involve taking part in an interview to obtain your views and insights regarding the research topic.

Risks and discomforts

There are no known risks associated with this research.

Potential benefits

There are no known direct benefits to you that would result from your participation in this research.

Protection of confidentiality

We will do everything we can to protect your privacy. Your identity will not be revealed in any publication resulting from this study. Your personal details will also not be revealed under any circumstances.

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from this study.

Appendix G (con't)

Contact information

If you have any questions or concerns about this study or if any problems arise, please contact Ms. Fanny Tang at (852) 3120 2678.

Consent

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Participant's Name ________________________________

Participant's signature________________________________

Date:_________________

A copy of this consent form should be given to you.

Appendix H

Interview Schedule

Target Interviewee: Managers with experience in the recruitment of graduates studying Science or Engineering Programmes and Testing and Certification Programmes

Each individual interview will take around 45 minutes to investigate

1. the interviewee's experience in recruiting graduates from the higher education institutes entering T&C industry
2. their views on the training received by the graduates in the higher education institutes
3. their views on the work readiness for the graduates studying Science or Engineering Programmes and Testing and Certification Programmes
4. their comments on the graduates' competence
5. their views on the alignment of QF standards with the curriculum

Rundown for the interview

	Sessions	**Duration**
1	Briefing and introduction to the research	10 mins
2	Warming up and facilitation	5 mins
3	Interview	45 mins

	Semi-structured interview questions
13.	What are the entry requirements to apply the technical posts in your company?
14.	What are the duties of the jobs? Do they meet your expectation?
15.	What do you think about the training that science and engineering students receive in

	higher education institutes? Are the academic subjects relevant to the market needs?
16.	In terms of work readiness, has the science and engineering graduates in the higher education institutions are well-equipped to enter the T&C industry (such as meeting the market needs or gain employment opportunities)? If not, how the the higher education institution can bridge the gap?
17.	What are your views regarding the competence of new graduate employees studying Science or Engineering programme and Testing and Certification programme in your organisation?
18.	What are some of the job-specific competencies that you think the new employees of i) Science or engineering graduates; and ii) T&C graduates are lacking?
19.	What do you think is the extent of skills gap among the graduate employees?
20.	How has the organisational culture hindered or supported the employees from developing competencies and skills that match organisational needs?
21.	What are your views regarding the alignment of curriculum with QF competency standards for T&C industry? How do think about the coverage of QF competency standards in the curriculum in higher education institutes?
22.	What do you think of the depth of work and the breadth of work? How much depth works best for skill development in the T&C industry?
23.	How do you comment on the depth of works and breadth of works for i) Science or engineering graduates; and ii) T&C graduates?
24.	What are your views regarding the curriculum design for i) Science or engineering graduates; and ii) T&C graduates?

Appendix I

Phase 1 - Familiarisation with data by note taking – Participant A

Respondent A

Semi-structured interview questions	Note
1) What are the entry requirements to apply the technical posts in your company?	
The position we are recruiting for is engineering officer. The recruit should hold a Bachelor of Science in physics, materials science, electronics, or a related discipline. Currently, we are also recruiting graduates in testing and certification disciplines.	→ entry requirement → recruit T&C graduates
2) What are the duties of the jobs? Do they meet your expectations?	
First, I would like to tell you what kinds of services our customers request. Our lab provides electronic testing and reliability testing services, and we mainly serve public utilities such as the Mass Transit Railway (MTR) and Hong Kong Electric. We also have customers from the area of manufacturing and product design. We provide variety of service to ensure we have sufficient competitiveness. Hence, they are not simply looking for testing. They also require prototyping services in product design and small lot production, so we should provide a total solution. Therefore, our engineering officers should have knowledge in electromagnetic compatibility (EMC) testing and reliability testing. I would also consider knowledge of circuit design and printed circuit-board manufacturing a definite advantage.	→ electronic test → manufacturing & design → TC : competitiveness → EMC + reliability
3) What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?	
I think that the subjects they learn in science/engineering programmes are relevant to our jobs and ready to work in technical field. Let me share my own experience. I recruited a fresh graduate who possessed a bachelor's degree in applied physics. He worked as an engineering officer and supported the team in conducting reliability testing. The tests involved numerous testing instruments. As the graduate was strong in physics, he quickly learned how to operate analytical instruments such as scanning electron microscopes and x-ray inspection. However, he had difficulty understanding the test standards. He even incorrectly interpreted the test procedures and produced inaccurate test results.	→ fresh graduate (S/E) → strong in operating instrument → weak in test
4) In terms of work readiness, are the science and engineering graduates in higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?	
I think that fresh science/engineering graduates understand basic testing concepts. However, they have little knowledge of testing standards, no solid experience, and no familiarity with how the tests are performed. Therefore, we employ science/engineering graduates who possess at least two years of working experience in a related field. They take up junior posts as engineering officers. They are entrusted with simple tasks first, such as preparing testing samples, conducting simple tests, entering test data and preparing test reports. Our professional and experienced staff, such as engineers and senior engineers, are responsible for conducting	S/E : not ready for working in lab → Not ready to work

Appendix I (con't)

Phase 1 - Familiarisation with data by note taking – Participant A

A.

complicated tests. Our senior staff also deal with customers in order to understand our customers' needs and the market trends. They convey this information to our junior staff through regular meetings and on-the-job training.	convey by meetings + training.
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?	
We have 16 staff members. Fourteen of them studied science/engineering, and two of them studied T&C. Only for those who possess a bachelor's degree in T&C do we recruit fresh graduates. Compared to science and engineering graduates, T&C graduates demonstrate high skills and abilities in testing.	- S/E no. > T&C - skilful: T&C.
6) What are some of the job-specific competencies that you think new employees who are i) science or engineering graduates or ii) T&C graduates lack?	
Regarding science and engineering graduates, they have in-depth knowledge of concepts and theories. For example, electronic graduates have solid knowledge of electric circuit design. Other than testing jobs, electronic graduates can support our research and development projects tailored to our customers. However, T&C graduates have a weak understanding of the concepts and theories taught in higher education institutions. Hence, they are not quite competent enough to handle the projects. Science or engineering (S/E) graduates have more flexibility in their jobs.In terms of their competence in testing, T&C graduates are definitely better than S/E graduates. They have broad knowledge of different testing methods. Even without detailed briefing and training, T&C graduates are ready to handle different tests properly, and they strictly follow the test standards. However, S/E graduates have less knowledge of testing. They take more time to learn and require detailed explanations from their supervisor. They perform the tests less skilfully than T&C graduates.	S/E: in-depth knowledge. concept → T&C: weak in concept - S/E: project base - T&C: broad knowledge but follow test strictly. - S/E: less skilful.
7) What do you think is the extent of the skills gap among the graduate employees?	
The skills gap for S/E graduates is their ability to understand and interpret test standards. They take a long time to learn and sometimes make incorrect interpretations. Incorrect interpretations of test standards lead to incorrect test results. For T&C graduates, their creativity in developing new testing technologies and their exploration of new testing methods is poor. They just follow work instructions when conducting tests.	Gap: S/E: incorrect interpretation of test T&C: explore new test but follow work instruction only
8) How has the organisational culture hindered or supported employees in terms of developing competencies and skills that match organisational needs?	
Because of the lack of subventions from the government, our organisation is actually a profit-making organisation. This message has been clearly conveyed from senior- to junior-level staff. I encourage them to explore and develop new testing services. I also encourage them to learn new technologies by attending seminars and workshops to enhance their knowledge.	→ Profit making → personal development is important

Appendix I (con’t)

Phase 1 - Familiarisation with data by note taking – Participant A

A

9) What are your views regarding the alignment of curricula with QF competency standards for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?	
I do not know anything about QF standards. For me, I think that the laboratory management system is more important than QF standards. As far as I know, QF standards refer to work skills that T&C practitioners should possess. The standards relate to personal competence. Instead of QF standards, I am mostly concerned with the operation of my laboratory—whether or not it is properly operated.	→ not much coverage in QF → laboratory mangmt is important than QF
10) What do you think of the depth of work and the breadth of work? How much depth works best for skill development in the T&C industry?	
Let me explain my expectations. Besides conducting routine testing jobs, employees should possess the following: 1)The ability to conduct multiple tests simultaneously; 2) The ability to communicate with customers; 3)In-depth knowledge of machine calibration; 4)Solid report-writing skills; 5)Familiarity with the process flow of testing; 6)Machine reparation skills. Regarding the depth of work, I expect employees to demonstrate the following: 1)A good understanding and application of the concepts and theories of testing to solve problems; 2)The ability to conduct tests with high accuracy. Personally, I prefer to have staff capable of providing “breadth of work” because I can fully utilise the manpower resources to carry out more tasks.	→ multi-tasks & good communication → writing skills → problem solving → breadth of work is prefer., better utilization.
11) What would you say about the depth of work and the breadth of work for i) science or engineering graduates and ii) T&C graduates?	
I think that science or engineering graduates can demonstrate their ability to provide ‘depth of work’. They can apply theories to solve technical problems for our customers. Regarding T&C graduates, they have knowledge in various testing methods. We do not need to spend much time training them.	→ S/E : depth of work → T&C: breadth of work.
12) What are your views regarding the curriculum design for i) science or engineering graduates and ii) T&C graduates?	
I would recommend strengthening the syllabi in terms of principles and theories for T&C students. For S/E graduates, they should have training in test standards to ensure that they have a good understanding of test procedures.	→ strengthen theory on tests

Appendix J

Phase 1 - Familiarisation with data by note taking – Participant B

Respondent B

Semi-structured interview questions	Note
1) What are the entry requirements to apply the technical posts in your company?	
The position we are recruiting for is testing technologist. The minimum requirement is a diploma from a higher education institution in science/engineering, electrons engineering/mechanical engineering or a testing discipline, with no work experience required. That means we welcome fresh graduates to apply to our posts. Four years ago, the majority of our graduates studied science/engineering. In recent years, we have received more applications from fresh graduates studying testing and certification and fewer applications from science/engineering graduates. The reason is that electronic/mechanical graduates look for jobs at construction firms and electronics companies. Thus, around 90% of our graduates studied testing and certification. By the way, I would like to share that placement or internship programmes have been helpful for us because they give us opportunities to find suitable candidates.	– fresh graduate are welcomed. → more T & C graduate than S/E → placement program is prefer.
2) What are the duties of the jobs? Do they meet your expectations?	
The services our laboratory provides are toy testing and other testing jobs. Toy testing is a competitive service among the other tests because there are lots of testing lab capable to provide the services. I would also like to share my views on science/engineering and T&C graduates. In fact, there are no differences in the duties of the jobs allocated to these groups of graduates. However, I have made the following observations. Science/engineering graduates demonstrate strength in understanding theory and knowledge and can therefore understand the principles of tests. However, they are poor at conducting tests practically and require a long time to learn the testing instruments. They are also weak in the concepts of quality assurance and quality control. T&C graduates are strong in their test-conducting skills and quickly learn how to operate the testing instruments, exhibiting higher productivity. Less training time is required for T&C graduates. I think that they could bring immediate benefits to my company. However, they are not strong in theory, such as the principles of circuit design or system design, when compared to S/E graduates. In my view, S/E graduates are superior in terms of migrating to the next level in their career ladder.	→ toy testing → competitive → S/E strong in theory, poor in testing. → long training time → T&C take less time on training. → S/E easy to be promoted.
3) What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?	
In terms of employment readiness, I think that the subjects they learn in science/engineering programmes, especially electronic engineering or mechanical engineering, are relevant to the job and skill requirements. As the business is growing in the construction industry, there is a high demand for graduates in mechanical or electronic disciplines to enter construction firms. The graduates receive higher salaries than they would working in testing laboratories. The academic subjects are more relevant to the market related to their subject area (e.g., the post of a mechanical engineer in a construction company).	→ ready to work → training relevant to market needs

Appendix J (con't)

Phase 1 - Familiarisation with data by note taking – Participant B

B

4) In terms of work readiness, are science and engineering graduates in the higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?	
Since S/E graduates are weak in conducting tests practically, they cannot skilfully handle testing instruments and require a long time to learn them. Thus, S\E graduates may not be equipped well to enter the T&C market. Normally, they require at least two years to familiarize themselves with the job and pick it up well. However, we witness a high turnover rate for graduates who have worked less than two years. To help S/E graduates adapt to the working environment and familiarize themselves with the job, I think that placement or internship programmes organised by higher education institutions can help. Through such programmes, students could understand and become acquainted with the nature of the job, the workflow and the operations and environment in testing laboratories. It would be a good opportunity for students to consider whether they are interested in this field. That is why our S/E graduates who have participated in internships at our company are more stable, with a small turnover rate.	S/E not ready to work in testing lab – placement program can help – recruit experienced S/E graduate with testing experience.
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?	
We have 30 staff members in total. Of them, 25 studied T&C, and 5 studied science/engineering. Because of the nature of jobs in testing laboratories, high productivity is required in order to meet the short delivery times customers expect. We expect fresh graduates to be well-equipped and ready to work without requiring a long training period. That is why we recruit more T&C graduates.	T&C graduate: – high productivity – less training time
6) What are some of the job-specific competencies that you think new employees who are i) science or engineering graduates or ii) T&C graduates lack?	
Due to the fast-changing technology and product development, to meet customer and legislative requirements for product safety, more and more new testing standards are being developed. From my point of view, both S/E graduates and T&C graduates have insufficient knowledge of new and emerging test standards because the standards they learned in university are not the most up-to-date test standards.	Both S/E & T&C graduate need to strengthen ability to explore new test standards
7) What do you think is the extent of the skills gap among the graduate employees?	
Regarding S/E graduates, they do not have much knowledge of test standards. For example, graduates in electronic engineering discipline are strong in printed circuit-board design and mathematics. However, they may not possess knowledge of how to test electronic products to ensure compliance with the test standards of different regions (e.g., the UK, Japan). They require more time to learn different testing methods and test instruments through on-the-job training. Hence, they require more time to adapt to the environment in a testing laboratory. We require fast delivery times for our customers. S/E graduates are not skilful in handling test instruments, and they require a longer learning time to familiarize	S/E graduates less knowledge in test standards → different region standards → T&C: productive & skilful, less training time

Appendix J (con't)

Phase 1 - Familiarisation with data by note taking – Participant B

B

themselves with new test standards as compared to T&C graduates. T&C graduates can conduct new tests in a short lead time and be more productive.	conduct new test by T&C graduate.
8) How has the organisational culture hindered or supported the employees in terms of developing competencies and skills that match organisational needs?	
Due to the fast-growing product development and rapid technological changes, product compliance is crucial and leads to a competitive business in the T&C industry. Short delivery times for testing services is our basic goal. Apart from our routine testing services and test reports, we also provide modification services to help customers identify problems, modify products and correcting errors. Graduates can have opportunities to learn more about our modification services such as failure analysis. Graduates who have worked at least two years in my company can get involved in modification services.	- competitive business in testing high - valued added services required experienced staff
9) What are your views regarding the alignment of curricula with QF competency standards for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?	
I think that the alignment of curricula with QF competency standards is important to ensure that higher education institutes build up undergraduates in the correct direction and provide competent graduates to enter the T&C industry. The coverage of QF should clearly distinguish between hardline and softline toys in physical and mechanical tests.	align basically hardline & softline toy should be separated
10) What do you think about the depth of the work and the breadth of work? How much depth works best for skill development in the T&C industry? (Follow up question) What would you say about the depth of work and the breadth of work for i) science or engineering graduates and ii) T&C graduates?	
If graduates are capable of providing breadth of work, they could easily find employment opportunities. I could assign different tasks to them. Personally, I have significant flexibility in terms of manpower allocation. For the graduates, they can determine their interests when they are exposed to different tasks. I think T&C graduates belong to this category. If graduates are capable of providing depth of work, they have fewer opportunities to work in other tasks and may not identify their interests. I think S/E graduates belong to this category. In my own case, I prefer staff capable of providing breadth of work because I can fully utilise the manpower resources to carry out more tasks.	T&C: - breadth of work - more employment opportunities S/E: - depth of work - less opportunities - prefer breadth of work
11) What are your views regarding the curriculum design for i) science or engineering graduates and ii) T&C graduates?	
Electrocompatibility (EMC) testing is vital for product compliance. However, I have observed that both S/E graduates and T&C graduates do not have much knowledge and are weak in this area, including the working principles and the test requirements. Hence, I would highly suggest increasing the coverage and strengthening undergraduates' knowledge of EMC testing.	- EMC testing is necessary.

Appendix K

Phase 1 - Familiarisation with data by note taking – Participant C

Respondent C

Semi-structured interview questions	Note
1) What are the entry requirements to apply for technical posts in your company?	
I supervise a team of 44 engineers that provides mainly hardline testing services on products including toys, furniture, and household products. To be considered for the position of engineer, applicants must hold a degree with a major in science or engineering (S/E) subjects such as physics, product engineering, and testing and certification (T&C). We consider new graduates. We offer applicants who hold qualifications below degree level (e.g., higher diplomas) lower-level positions (e.g., assistant engineer).	– hardline testing → S/E & T&C graduate ⇒ fresh graduate are welcomed
2) What are the duties of the jobs? Do they meet your expectations?	
Recent graduates' main duty is conducting tests, and each person focuses on a specific test first. Once they are familiar with the test, we assign them to conduct different tests under the supervision of team leaders. Once they are familiar with all the required tests, they can perform the tests independently. Because our samples are provided by customers in limited numbers and controlled quantities, and some of the samples are very expensive, we must ensure that the tests are performed correctly and the samples are utilised properly. Thus, when recent graduates conduct the tests, they are closely monitored by their supervisors to avoid errors. Because recent graduates lack experience, they seldom meet my expectations.	→ testing mainly – with closely monitored by leaders
3) What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?	
Generally, the training is relevant to job requirements and market needs. Because T&C is an extremely competitive industry, we must maintain high productivity and quality. T&C graduates easily meet these requirements. They usually demonstrate knowledge of different tests, and they quickly acquire the necessary skills to perform the tests. In other words, because T&C students learn a variety of test methods at university, we can shorten the lead time for training. This helps us to meet our production targets and deliver fast testing services to our customers. S/E graduates, on the other hand, have strong research and development skills, and they can explore and develop new services.	– training vs market needs → T&C : meet expectation, high productivity & knowledge in various tests → S/E : strong in research & concept – new services
4) In terms of work readiness, are science and engineering graduates in the higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?	
S/E graduates often lack knowledge of and experience with laboratory management, specifically equipment maintenance and calibration, and	

Appendix K (con't)

Phase 1 - Familiarisation with data by note taking – Participant C

C

the ISO 17025 quality system, which is something I assumed they would learn at university. This is the most fundamental knowledge graduates should learn if they intend to work in testing laboratories. Hence, knowledge about and concepts in laboratory management should be strengthened for undergraduates.	→ lack of exposure & knowledge in laboratory management system 17025
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?	
As mentioned previously, we are concerned about productivity. We must provide services with a short turn-around time. In light of these requirements, T&C graduates performed better than S/E graduates, as even recent graduates quickly learned different tests. Additionally, they can interpret test standards accurately and work out the tests. However, they are weak in failure and root cause analysis, which are skills students develop in subjects focused on research and development. In contrast, S/E graduates perform better than T&C graduates in exploring and developing new test methods, but recent S/E graduates have lower productivity. Consequently, S/E graduates with at least two years' experience working in testing labs are preferred to recent graduates.	→ concerned of productivity. → T&C better than S/E due to learn more test & interpret test methods. – S/E can develop test methods
6) What are some of the job-specific competencies that you think new employees who are (i) science or engineering graduates or (ii) T&C graduates lack?	
The ISO 17025 laboratory management system is the most fundamental knowledge graduates should have, and they should know how to maintain adequate laboratory standards. Furthermore, ethics are essential to ensure impartiality is maintained. I know T&C graduates receive training on both these topics, but S/E graduates do not. Hence, I need to spend more time training S/E graduates.	S/E : strengthen knowledge in – ISO 17025 – ethics
7) What do you think is the extent of the skills gap among the graduate employees?	
Because our testing instruments are commonly used and adopted in the T&C industry, they are considered industrial grade rather than laboratory grade. Thus, although S/E graduates are familiar with many testing instruments, some equipment is new to them, and they have to spend time learning about the equipment and understanding the working principles. T&C graduates are more suitable because they learn these working principles at universities. During job rotation, they quickly learn new tests and conduct tests with minimal supervision.	- S/E graduate are weak in understand equipment (using). - spend more time to learn
8) How has the organisational culture hindered or supported the employees in terms of developing competencies and skills that match organisational needs?	
Performance is measured by team rather than individual, based on factors such as delivery time, number of jobs completed, and number of new customers secured. The factors used to measure performance differ from department to department due to the variations in the nature of the work. For example, performance in the chemical test department is	→ performance measured by team

Appendix K (con't)

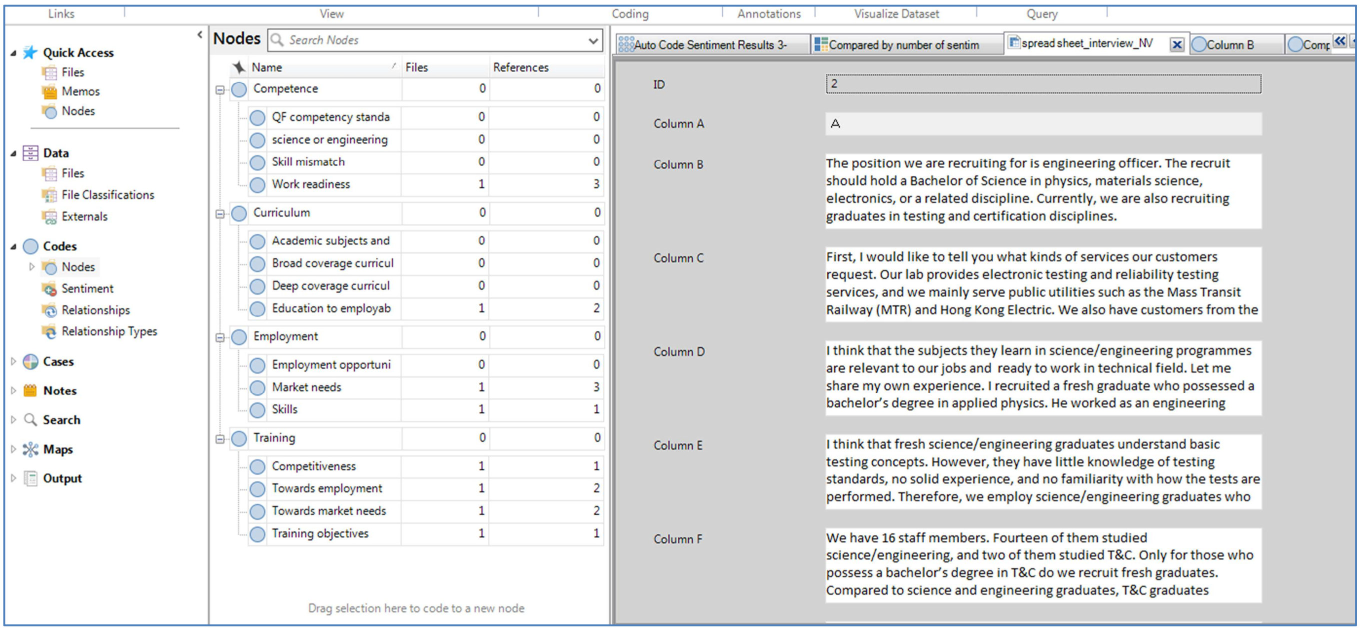
Phase 1 - Familiarisation with data by note taking – Participant C

C

measured based on outcomes instead of productivity, and success rates and customer satisfaction indexes are part of their measurement parameters. We clearly communicate our measurement parameters to our graduates from their first day to improve team performance and develop individuals' skills. For us, productivity is crucial. We have job rotation schemes to train graduates on multitasking, and graduates are closely mentored by their supervisors.	→ communicate to staff. → All concerns productivity & graduate are mentored by leader.
9) What are your views regarding the alignment of curricula with QF competency standards for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?	
May I ask what QF is? (I explained the details about QF to employer C and listed the 51 clusters of competence standards). I agree QF is useful, but I am not familiar with the QF standards.	Agree but not clear QF
10) What do you think about the depth of the work and the breadth of work? How much depth works best for skills development in the T&C industry? (Follow-up question) What would you say about the depth of work and the breadth of work for (i) science or engineering graduates and (ii) T&C graduates?	
I definitely support breadth of work because my team's performance is measured by productivity. As mentioned, T&C graduates have knowledge of various tests and working principles. This is very useful to our team.	- breadth of work necessary - T&C graduate exhibit this ability
11) What are your views regarding the curriculum design for (i) science or engineering graduates and (ii) T&C graduates?	
Ultimately, from a commercial point of view, product recalls and product failure are our customers' main concerns. They need to ensure adequate quality to avoid product recalls and failure. That's why they send their products to us for testing. However, S/E and T&C graduates have insufficient knowledge in of these topics. Once again, their knowledge of laboratory management and quality management should be strengthened.	- strengthen product recalls & product failure analysis. - QM & lab management system

Appendix L

Examples of initial codes generation (Phase 2) by using NVivo 12



Appendix M

Theme Identification Process

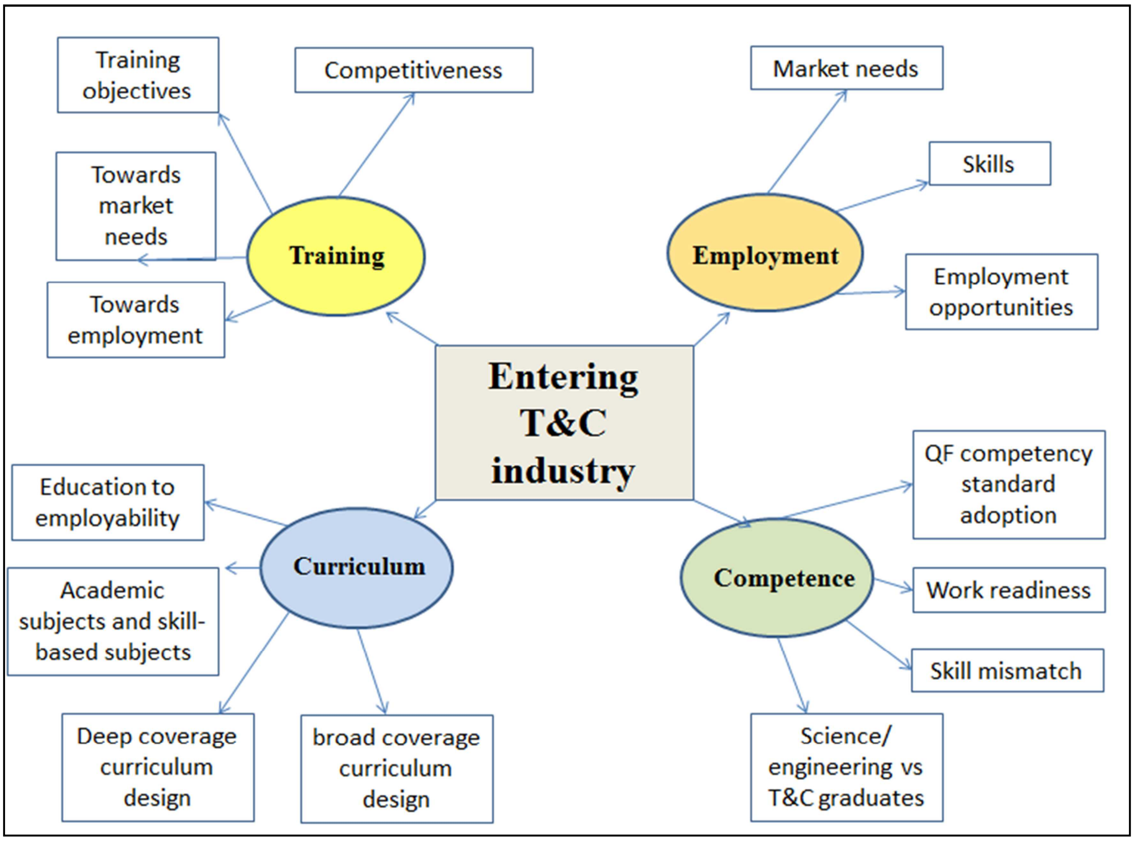


Figure 5.4: Potential themes with related nodes

The four sub-themes identified in the theme of 'training' were refined into three sub-themes of *competitiveness*, *market needs* and *employment readiness* (see Figure 5.5).

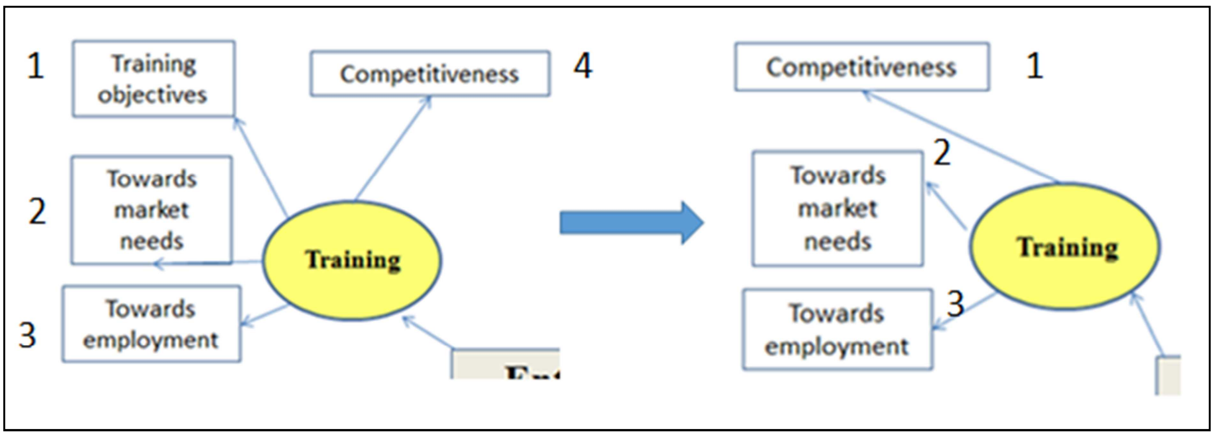


Figure 5.5: Refined from four sub-themes to three sub-themes in 'training'

For the sub-themes in ‘curriculum’, *deep coverage curriculum design* and *broad coverage curriculum design* were merged and represented by *curriculum design* (see Figure 5.6).

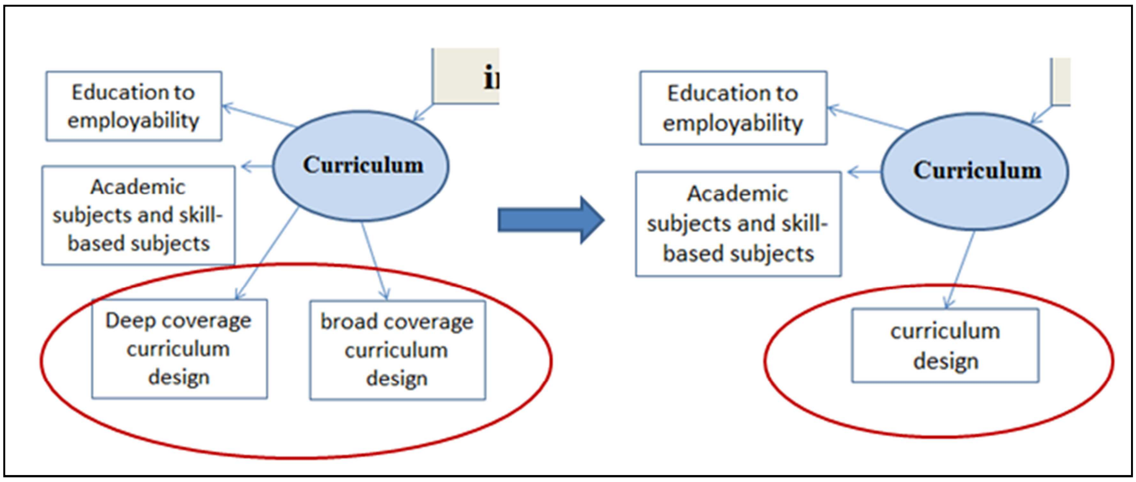


Figure 5.6: Merged ‘deep coverage curriculum design’ and ‘broad coverage curriculum design’ into ‘curriculum design’

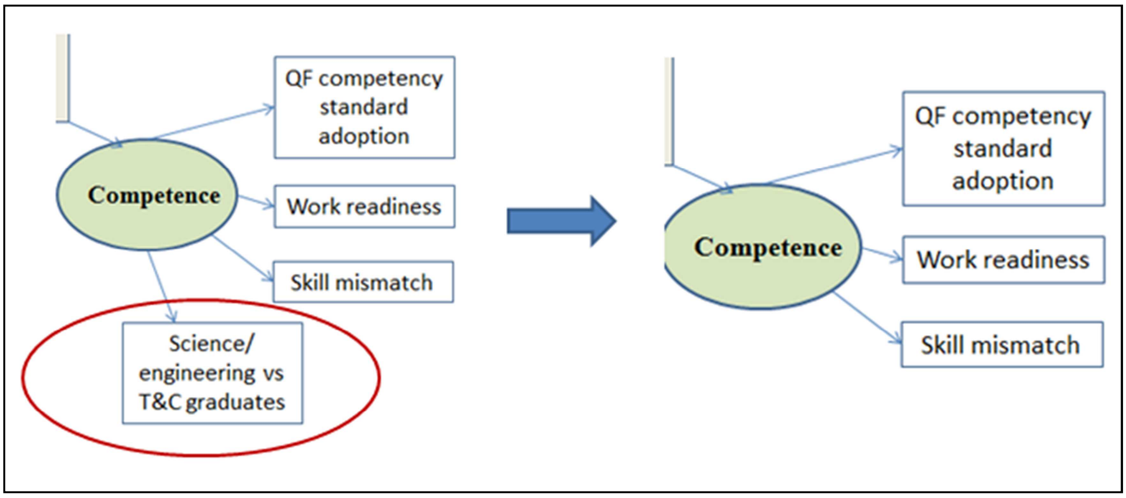


Figure 5.7: Refined from four sub-themes to three sub-themes under ‘competence’

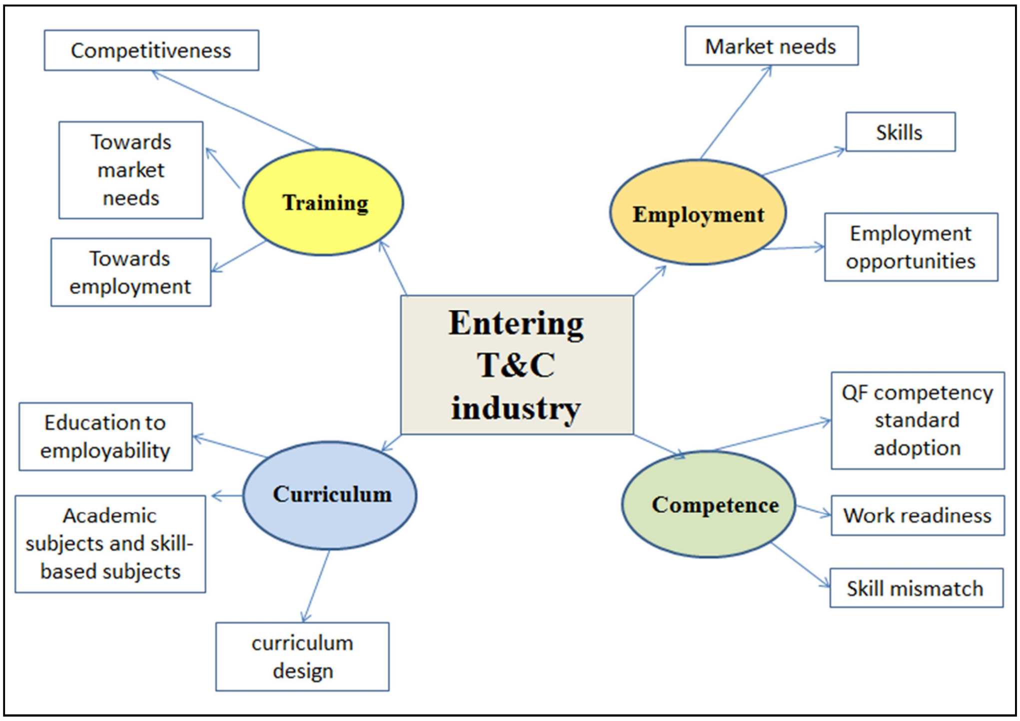


Figure 5.8: Themes and sub-themes after review

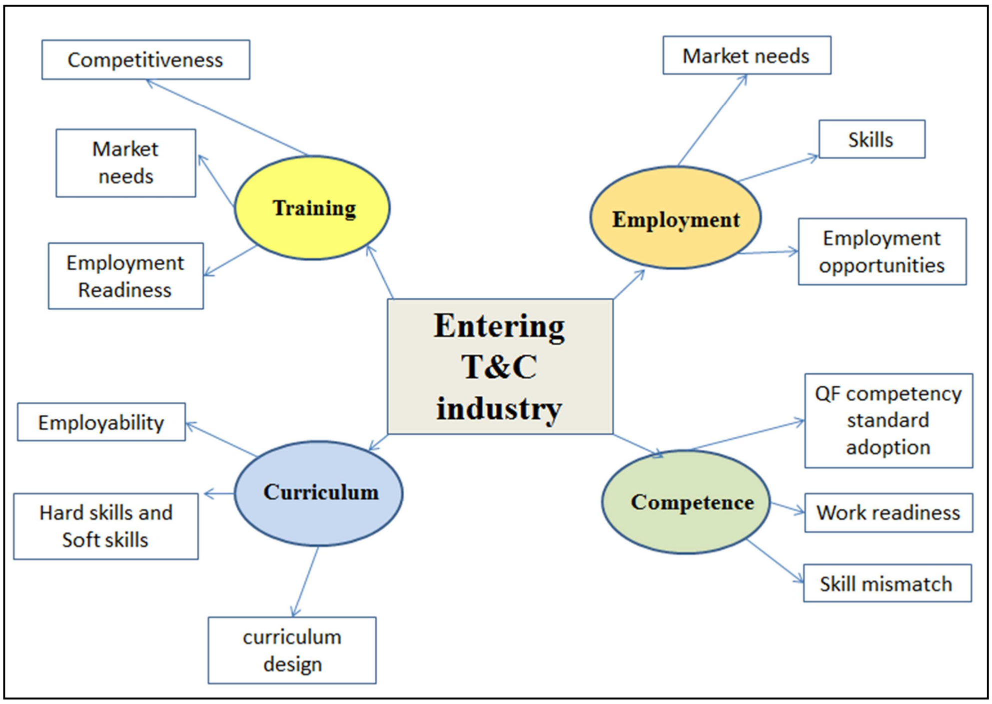
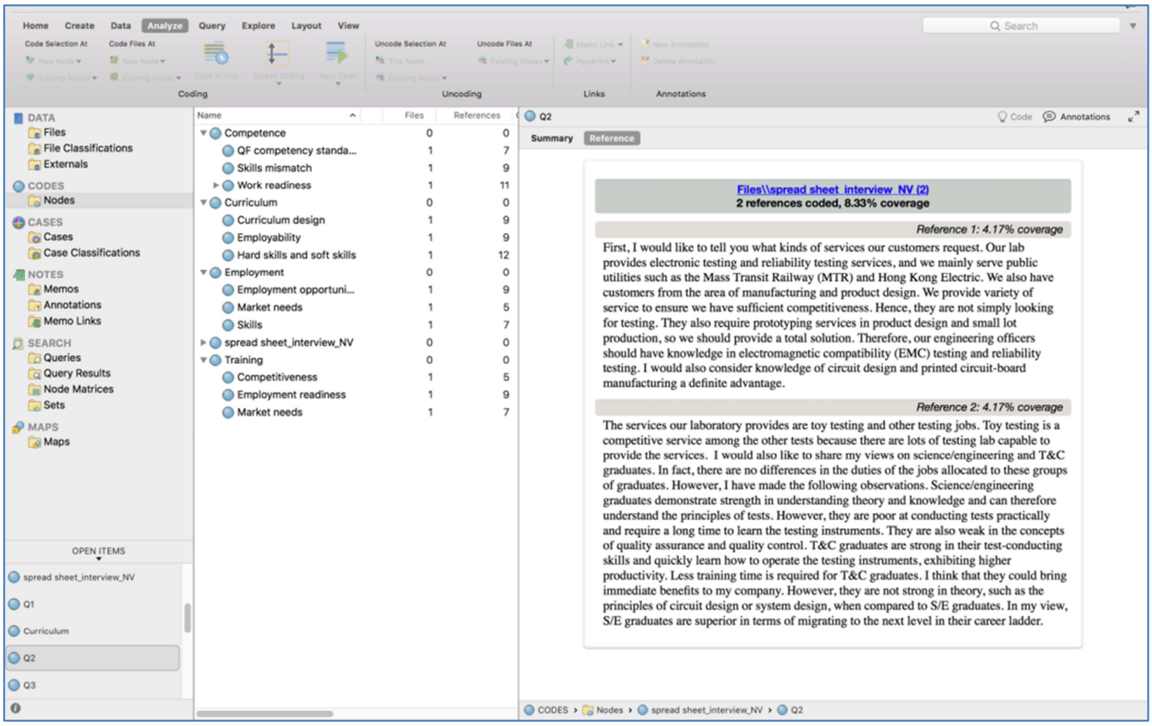


Figure 5.9: Finalized thematic map

Appendix N

Examples of review the nodes and cross-check the transcripts (Phase 5)

by using NVivo 12



Appendix O

Matrix Table for Competency Mapping with Courses

Name of course		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Unit of analysis	A																
	B																
	C																
	D																
	E																
	F																
	G																
	H																
	I																
Name of course		Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33
Unit of analysis	A																
	B																
	C																
	D																
	E																
	F																
	G																
	H																
	I																
Name of course		Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50
Unit of analysis	A																
	B																
	C																
	D																
	E																
	F																
	G																
	H																
	I																

Note: Course titles are given in the first column and the codes of competency in the first row. The numbers written under the codes of competency represent the total number of courses correlating to the respective cluster units of competency. The correlation of numbers written beside each course indicate the number of corresponding cluster units of competency. Courses that include cluster units of competency are designated as ‘UC courses’ in the table, and courses that do not include any cluster units of competency are designated as ‘Non-UC courses. The abbreviation ‘UC’ stands for ‘unit of competency’. Some courses may include more than one cluster unit of competency.

Appendix P

University A – Frequency Distribution of UC Courses in the Codes

Codes	No. of UC courses	No. of credits	UC courses
Q1	1	3	• Test Method, Measurement and Uncertainty
Q2	1	3	• Test Method, Measurement and Uncertainty
Q3	1	3	• Test Method, Measurement and Uncertainty
Q4	1	3	• Chemical Principles for Testing and Analysis
Q5	1	3	• Chemical Principles for Testing and Analysis
Q6	18	54	• Chemistry Laboratory I • Chemistry Laboratory II • Chemistry Laboratory III • Applied Chemistry Laboratory • Experimental Techniques in Chemistry • Inorganic Chemistry II Laboratory • Organometallic Chemistry & Catalysis Laboratory • Industrial Electrochemistry Laboratory • Polymer Laboratory • Advanced Physical Chemistry Laboratory • Chemical & Bioprocess Technology Laboratory • General Laboratory Techniques and Safety • Chromatographic Analysis Laboratory • Organic Chemistry II Laboratory • Analytical Chemistry II Laboratory • Quality Management and Laboratory Accreditation • Advanced Analytical Techniques Laboratory
Q7	5	15	• General Laboratory Techniques and Safety • Microbiology • Food Microbiology • Microbiology and Toxicology • Microbiological Techniques
Q8	10	30	• Analytical Chemistry • Analytical Chemistry I • Analytical Chemistry II • Analytical Spectroscopy • Analytical Chemistry III • Analytical Chemistry II Laboratory • Advanced Analytical Techniques for Food Hazards • Advanced Analytical Techniques

			• Advanced Analytical Techniques Laboratory • Advanced Analytical Techniques Laboratory • Capstone Seminar in Analytical Chemistry
Q9	10	30	• Analytical Chemistry, Analytical Chemistry I • Analytical Chemistry II, Analytical Spectroscopy • Analytical Chemistry III • Analytical Chemistry II Laboratory • Advanced Analytical Techniques for Food Hazards • Advanced Analytical Techniques • Advanced Analytical Techniques Laboratory • Advanced Analytical Techniques Laboratory • Capstone Seminar in Analytical Chemistry
Q10	10	30	• Analytical Chemistry • Analytical Chemistry I • Analytical Chemistry II • Analytical Spectroscopy • Analytical Chemistry III • Analytical Chemistry II Laboratory • Advanced Analytical Techniques for Food Hazards • Advanced Analytical Techniques • Advanced Analytical Techniques Laboratory • Advanced Analytical Techniques Laboratory • Capstone Seminar in Analytical Chemistry
Q11	5	15	• Organic Chemistry • Organic Chemistry I • Food Analysis • Organic Chemistry II • Organic Chemistry II Laboratory
Q12	6	18	• Organic Chemistry • Organic Chemistry I • Chromatographic Analysis • Chromatographic Analysis Laboratory • Organic Chemistry II Laboratory • Analytical Chemistry II Laboratory
Q13	4	12	• Organic Chemistry • Organic Chemistry I • Organic Chemistry II • Organic Chemistry II Laboratory
Q14	1	3	• Microbiological Techniques

Q15	1	3	• Microbiological Techniques
Q16	1	3	• Environmental, Medicinal • Food and Other Commodities Testing
Q17	3	9	• Environmental, Medicinal • Food and Other Commodities Testing, • Pollution Control & Environmental Analysis, • Pollution Control & Environmental Analysis Laboratory
Q44	3	9	• Quality & Food Safety Management • Quality Management and Laboratory Accreditation • Principles of Quality Assurance
Q45	1	3	• Test Method, Measurement and Uncertainty
Q46	1	3	• Test Method, Measurement and Uncertainty
Q47	1	3	• Test Method, Measurement and Uncertainty
Q48	1	3	• Inspection and Certification
Q50	2	6	• Inspection and Certification • Principles of Quality Assurance
Total credits		258	

Appendix Q

University B – Frequency Distribution of UC Courses in the Codes

Codes	No. of UC courses	No. of credits	UC courses
Q6	6	18	Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry Laboratory, Instrumental Analysis Lab, Instrumentation & Data Acquisition Lab, Integrated Laboratory for Analytical Testing Science and Chemical Testing Lab Management and Accreditation
Q8	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences
Q9	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences
Q10	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences
Q11	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences
Q12	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences

Q13	6	18	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Materials Testing & Characterisation, Spectroscopic Techniques for Structure Determination and Dissertation in Analytical & Testing Sciences
Q1	5	15	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Instrumentation & Data Acquisition Lab and Materials Testing & Characterisation
Q45	5	15	Analytical Chemistry & Testing Sci Tutorial I, Chemistry Laboratory for Analytical Testing Science, Analytical Chemistry & Testing Sci Tutorial II, Instrumentation & Data Acquisition Lab and Materials Testing & Characterisation
Q16	1	3	Environmental Analysis
Q17	1	3	Environmental Analysis
Q50	1	3	Chemical Testing Lab Management and Accreditation
Q51	1	3	Chemical Testing Lab Management and Accreditation
Total credits		168	

Appendix R

University C – Frequency Distribution of UC Courses in the Codes

Codes	No. of UC courses	No. of credits	UC courses
Q1	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q2	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q3	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q4	3	9	• Quality Management for Science & Technology • Safety & Reliability for Science & Technology • Audit, Inspection & Certification
Q5	3	9	• Quality Management for Science & Technology • Safety & Reliability for Science & Technology • Audit, Inspection & Certification
Q6	1	3	• Laboratory Safety & Good Laboratory Practice
Q7	2	6	• Laboratory Safety & Good Laboratory Practice • Selected Chemical & Microbiological T&C Standard
Q8	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques • Chemical & Microbiological T&C in Practice
Q9	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques • Chemical & Microbiological T&C in Practice
Q10	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques • Chemical & Microbiological T&C in Practice
Q11	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques • Chemical & Microbiological T&C in Practice
Q12	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques • Chemical & Microbiological T&C in Practice
Q13	3	9	• Analytical Chemistry for Product Testing • Chemical & Microbiological Analytical Techniques

			• Chemical & Microbiological T&C in Practice
Q14	2	6	• Microbiology & Toxicology • Selected Chemical & Microbiological T&C Standards
Q15	2	6	• Microbiology & Toxicology • Selected Chemical & Microbiological T&C Standards
Q16	1	3	• Selected Chemical & Microbiological T&C Standards
Q17	1	3	• Selected Physical & Mechanical T&C Standards
Q18	2	6	• Physical & Mechanical Behaviour of Materials • Principles of Physical & Mechanical Testing
Q23	2	6	• Physical & Mechanical Behaviour of Materials • Principles of Physical & Mechanical Testing
Q25	3	9	• Physical & Mechanical Behaviour of Materials • Principles of Physical & Mechanical Testing • Physical & Mechanical T&C in Practice
Q26	3	9	• Physical & Mechanical Behaviour of Materials • Principles of Physical & Mechanical Testing • Physical & Mechanical T&C in Practice
Q27	3	9	• Physical & Mechanical Behaviour of Materials • Principles of Physical & Mechanical Testing • Physical & Mechanical T&C in Practice
Q28	2	6	• Selected Physical & Mechanical T&C Standards • Physical & Mechanical T&C in Practice
Q29	2	6	• Selected Physical & Mechanical T&C Standards • Physical & Mechanical T&C in Practice
Q30	2	6	• Selected Physical & Mechanical T&C Standards • Physical & Mechanical T&C in Practice
Q31	2	6	• Selected Physical & Mechanical T&C Standards • Physical & Mechanical T&C in Practice
Q32	2	6	• Selected Physical & Mechanical T&C Standards • Physical & Mechanical T&C in Practice
Q36	1	3	• Selected Electrical & Electronic T&C Standards
Q37	2	6	• Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q38	2	6	• Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q39	2	6	• Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q40	2	6	• Selected Electrical & Electronic T&C Standards

			• Electrical & Electronic T&C in Practice
Q41	2	6	• Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q42	2	6	• Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q43	3	9	• Electrical Safety & Energy Efficiency • Selected Electrical & Electronic T&C Standards • Electrical & Electronic T&C in Practice
Q44	5	15	• Principle of Production Design & Manufacturing Process Management • Quality Management for Science & Technology • Conformity Assessment & Laboratory Accreditation • Safety & Reliability for Science & Technology • Audit, Inspection & Certification
Q45	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q46	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q47	2	6	• Metrology & Calibration • Measurement Uncertainty & Test Method Development
Q48	6	18	• Principle of Production Design & Manufacturing Process Management • Quality Management for Science & Technology • Conformity Assessment & Laboratory Accreditation • Safety & Reliability for Science & Technology • Audit, Inspection & Certification • Management Systems for Inspection & Certification Bodies
Q50	6	18	• Principle of Production Design & Manufacturing Process Management • Quality Management for Science & Technology • Conformity Assessment & Laboratory Accreditation • Safety & Reliability for Science & Technology • Audit, Inspection & Certification • Management Systems for Inspection & Certification Bodies

Appendix S

Word count table

Word	Word Length	Word Count	Weighted Percentage (%)
Chemistry	9	40	9.66
Food	4	23	5.56
Laboratory	10	17	4.11
Analytical	10	10	2.42
Project	7	8	1.93
Advanced	8	7	1.69
Analysis	8	7	1.69
Biology	7	7	1.69
introduction	12	7	1.69
Subject	7	7	1.69
techniques	10	7	1.69
technology	10	7	1.69
biotechnology	13	6	1.45
environmental	13	6	1.45
Servicing	9	6	1.45
Life	4	5	1.21
Physical	8	5	1.21
Science	7	5	1.21
biochemistry	12	4	0.97
Chemical	8	4	0.97
General	7	4	0.97
Inorganic	9	4	0.97
introductory	12	4	0.97
management	10	4	0.97
microbiology	12	4	0.97
Nutrition	9	4	0.97
Organic	7	4	0.97
physiology	10	4	0.97
Principles	10	4	0.97
processing	10	4	0.97
Safety	6	4	0.97
Applied	7	3	0.72
bioprocess	10	3	0.72
Cell	4	3	0.72
Control	7	3	0.72
Human	5	3	0.72
molecular	9	3	0.72
Polymer	7	3	0.72

Quality	7	3	0.72
Research	8	3	0.72
Capstone	8	2	0.48
Catalysis	9	2	0.48
chromatographic	15	2	0.48
development	11	2	0.48
electrochemistry	16	2	0.48
experimental	12	2	0.48
Foods	5	2	0.48
Health	6	2	0.48
Healthy	7	2	0.48
Impact	6	2	0.48
Industrial	10	2	0.48
intermediate	12	2	0.48
Living	6	2	0.48
medicinal	9	2	0.48
organometallic	14	2	0.48
pharmacology	12	2	0.48
Pollution	9	2	0.48
Products	8	2	0.48
Testing	7	2	0.48
toxicology	10	2	0.48
accreditation	13	1	0.24
Approach	8	1	0.24
Assurance	9	1	0.24
Behind	6	1	0.24
biochemical	11	1	0.24
bioinformatics	14	1	0.24
Cancer	6	1	0.24
Cause	5	1	0.24
certification	13	1	0.24
China	5	1	0.24
Chinese	7	1	0.24
Code	4	1	0.24
Color	5	1	0.24
commercialization	17	1	0.24
commodities	11	1	0.24
Cosmetics	9	1	0.24
Crime	5	1	0.24
Csi	3	1	0.24
Culture	7	1	0.24
Cycle	5	1	0.24

developments	12	1	0.24
Diet	4	1	0.24
Dietary	7	1	0.24
Diseases	8	1	0.24
Dna	3	1	0.24
Drug	4	1	0.24
Earth	5	1	0.24
Ecology	7	1	0.24
Economic	8	1	0.24
Ecosystem	9	1	0.24
Educating	9	1	0.24
Elements	8	1	0.24
endangered	10	1	0.24
engineering	11	1	0.24
epidemiology	12	1	0.24
evaluation	10	1	0.24
Farm	4	1	0.24
Farmers	7	1	0.24
Fork	4	1	0.24
Fossil	6	1	0.24
Fuel	4	1	0.24
functional	10	1	0.24
Gases	5	1	0.24
Green	5	1	0.24
Hazards	7	1	0.24
Healthier	9	1	0.24
History	7	1	0.24
House	5	1	0.24
Hygiene	7	1	0.24
immunology	10	1	0.24
immunotechnology	16	1	0.24
Inspection	10	1	0.24
investigation	13	1	0.24
Lab	3	1	0.24
Laws	4	1	0.24
Learning	8	1	0.24
Materials	9	1	0.24
measurement	11	1	0.24
Medical	7	1	0.24
Medicine	8	1	0.24
metabolism	10	1	0.24
Method	6	1	0.24

Microbial	9	1	0.24
microbiological	15	1	0.24
Modern	6	1	0.24
Myth	4	1	0.24
nanotechnology	14	1	0.24
Natural	7	1	0.24
nutraceuticals	14	1	0.24
prevention	10	1	0.24
Process	7	1	0.24
production	10	1	0.24
Protein	7	1	0.24
Raw	3	1	0.24
Recent	6	1	0.24
regulations	11	1	0.24
rehabilitation	14	1	0.24
Risk	4	1	0.24
Rural	5	1	0.24
Sanitation	10	1	0.24
Scene	5	1	0.24
Selected	8	1	0.24
Seminar	7	1	0.24
Sensory	7	1	0.24
Service	7	1	0.24
Smell	5	1	0.24
spectroscopy	12	1	0.24
sustainable	11	1	0.24
Systemic	8	1	0.24
Taste	5	1	0.24
Test	4	1	0.24
Therapy	7	1	0.24
Topics	6	1	0.24
Treasure	8	1	0.24
Treatment	9	1	0.24
uncertainty	11	1	0.24
Vaccines	8	1	0.24
Waste	5	1	0.24
Water	5	1	0.24
			95.94

Appendix T

Transcripts of the semi-structure interview for Participant A

Semi-structured interview questions
1) What are the entry requirements to apply the technical posts in your company?
The position we are recruiting for is engineering officer. The recruit should hold a Bachelor of Science in physics, materials science, electronics, or a related discipline. Currently, we are also recruiting graduates in testing and certification disciplines.
2) What are the duties of the jobs? Do they meet your expectations?
First, I would like to tell you what kinds of services our customers request. Our lab provides electronic testing and reliability testing services, and we mainly serve public utilities such as the Mass Transit Railway (MTR) and Hong Kong Electric. We also have customers from the area of manufacturing and product design. We provide variety of service to ensure we have sufficient competitiveness. Hence, they are not simply looking for testing. They also require prototyping services in product design and small lot production, so we should provide a total solution. Therefore, our engineering officers should have knowledge in electromagnetic compatibility (EMC) testing and reliability testing. I would also consider knowledge of circuit design and printed circuit-board manufacturing a definite advantage.
3) What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?
I think that the subjects they learn in science/engineering programmes are relevant to our jobs and ready to work in technical field. Let me share my own experience. I recruited a fresh graduate who possessed a bachelor's degree in applied physics. He worked as an engineering officer and supported the team in conducting reliability testing. The tests involved numerous testing instruments. As the graduate was strong in physics, he quickly learned how to operate analytical instruments such as scanning electron microscopes and x-ray inspection. However, he had difficulty understanding the test standards. He even incorrectly interpreted the test procedures and produced inaccurate test results.
4) In terms of work readiness, are the science and engineering graduates in higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?

I think that fresh science/engineering graduates understand basic testing concepts. However, they have little knowledge of testing standards, no solid experience, and no familiarity with how the tests are performed. Therefore, we employ science/engineering graduates who possess at least two years of working experience in a related field. They take up junior posts as engineering officers. They are entrusted with simple tasks first, such as preparing testing samples, conducting simple tests, entering test data and preparing test reports. Our professional and experienced staff, such as engineers and senior engineers, are responsible for conducting complicated tests. Our senior staff also deal with customers in order to understand our customers' needs and the market trends. They convey this information to our junior staff through regular meetings and on-the-job training.
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?
We have 16 staff members. Fourteen of them studied science/engineering, and two of them studied T&C. Only for those who possess a bachelor's degree in T&C do we recruit fresh graduates. Compared to science and engineering graduates, T&C graduates demonstrate high skills and abilities in testing.
6) What are some of the job-specific competencies that you think new employees who are i) science or engineering graduates or ii) T&C graduates lack?
Regarding science and engineering graduates, they have in-depth knowledge of concepts and theories. For example, electronic graduates have solid knowledge of electric circuit design. Other than testing jobs, electronic graduates can support our research and development projects tailored to our customers. However, T&C graduates have a weak understanding of the concepts and theories taught in higher education institutions. Hence, they are not quite competent enough to handle the projects. Science or engineering (S&E) graduates have more flexibility in their jobs.In terms of their competence in testing, T&C graduates are definitely better than S&E graduates. They have broad knowledge of different testing methods. Even without detailed briefing and training, T&C graduates are ready to handle different tests properly, and they strictly follow the test standards. However, S&E graduates have less knowledge of testing. They take more time to learn and require detailed explanations from their supervisor. They perform the tests less skilfully than T&C graduates.
7) What do you think is the extent of the skills gap among the graduate employees?

	The skills gap for S&E graduates is their ability to understand and interpret test standards. They take a long time to learn and sometimes make incorrect interpretations. Incorrect interpretations of test standards lead to incorrect test results. For T&C graduates, their creativity in developing new testing technologies and their exploration of new testing methods is poor. They just follow work instructions when conducting tests.
8)	How has the organisational culture hindered or supported employees in terms of developing competencies and skills that match organisational needs?
	Because of the lack of subventions from the government, our organisation is actually a profit-making organisation. This message has been clearly conveyed from senior- to junior-level staff. I encourage them to explore and develop new testing services. I also encourage them to learn new technologies by attending seminars and workshops to enhance their knowledge.
9)	What are your views regarding the alignment of curricula with QF competency standards for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?
	I do not know anything about QF standards. For me, I think that the laboratory management system is more important than QF standards. As far as I know, QF standards refer to work skills that T&C practitioners should possess. The standards relate to personal competence. Instead of QF standards, I am mostly concerned with the operation of my laboratory—whether or not it is properly operated.
10)	What do you think of the depth of work and the breadth of work? How much depth works best for skill development in the T&C industry?
	Let me explain my expectations. Besides conducting routine testing jobs, employees should possess the following: 1)The ability to conduct multiple tests simultaneously; 2) The ability to communicate with customers; 3)In-depth knowledge of machine calibration; 4)Solid report-writing skills; 5)Familiarity with the process flow of testing; 6)Machine reparation skills. Regarding the depth of work, I expect employees to demonstrate the following: 1)A good understanding and application of the concepts and theories of testing to solve problems; 2)The ability to conduct tests with high accuracy. Personally, I prefer to have staff capable of providing "breadth of work" because I can fully utilise the manpower resources to carry out more tasks.

11) What would you say about the depth of work and the breadth of work for i) science or engineering graduates and ii) T&C graduates?
I think that science or engineering graduates can demonstrate their ability to provide ‘depth of work’. They can apply theories to solve technical problems for our customers. Regarding T&C graduates, they have knowledge in various testing methods. We do not need to spend much time training them.
12) What are your views regarding the curriculum design for i) science or engineering graduates and ii) T&C graduates?
I would recommend strengthening the syllabi in terms of principles and theories for T&C students. For S&E graduates, they should have training in test standards to ensure that they have a good understanding of test procedures.

Appendix U

Transcripts of the semi-structure interview for Participant B

Semi-structured interview questions
1) What are the entry requirements to apply the technical posts in your company?
The position we are recruiting for is testing technologist. The minimum requirement is a diploma from a higher education institution in science/engineering, electrons engineering/mechanical engineering or a testing discipline, with no work experience required. That means we welcome fresh graduates to apply to our posts. Four years ago, the majority of our graduates studied science/engineering. In recent years, we have received more applications from fresh graduates studying testing and certification and fewer applications from science/engineering graduates. The reason is that electronic/mechanical graduates look for jobs at construction firms and electronics companies. Thus, around 90% of our graduates studied testing and certification. By the way, I would like to share that placement or internship programmes have been helpful for us because they give us opportunities to find suitable candidates.
2) What are the duties of the jobs? Do they meet your expectations?
The services our laboratory provides are toy testing and other testing jobs. Toy testing is a competitive service among the other tests because there are lots of testing lab capable to provide the services. I would also like to share my views on science/engineering and T&C graduates. In fact, there are no differences in the duties of the jobs allocated to these groups of graduates. However, I have made the following observations. Science/engineering graduates demonstrate strength in understanding theory and knowledge and can therefore understand the principles of tests. However, they are poor at conducting tests practically and require a long time to learn the testing instruments. They are also weak in the concepts of quality assurance and quality control. T&C graduates are strong in their test-conducting skills and quickly learn how to operate the testing instruments, exhibiting higher productivity. Less training time is required for T&C graduates. I think that they could bring immediate benefits to my company. However, they are not strong in theory, such as the principles of circuit design or system design, when compared to S&E graduates. In my view, S&E graduates are superior in terms of migrating to the next level in their career ladder.
3) What do you think about the training that science and engineering students receive in

higher education institutes? Are the academic subjects relevant to the market needs?
In terms of employment readiness, I think that the subjects they learn in science/engineering programmes, especially electronic engineering or mechanical engineering, are relevant to the job and skill requirements. As the business is growing in the construction industry, there is a high demand for graduates in mechanical or electronic disciplines to enter construction firms. The graduates receive higher salaries than they would working in testing laboratories. The academic subjects are more relevant to the market related to their subject area (e.g., the post of a mechanical engineer in a construction company).
4) In terms of work readiness, are science and engineering graduates in the higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?
Since S&E graduates are weak in conducting tests practically, they cannot skilfully handle testing instruments and require a long time to learn them. Thus, S\E graduates may not be equipped well to enter the T&C market. Normally, they require at least two years to familiarize themselves with the job and pick it up well. However, we witness a high turnover rate for graduates who have worked less than two years. To help S&E graduates adapt to the working environment and familiarize themselves with the job, I think that placement or internship programmes organised by higher education institutions can help. Through such programmes, students could understand and become acquainted with the nature of the job, the workflow and the operations and environment in testing laboratories. It would be a good opportunity for students to consider whether they are interested in this field. That is why our S&E graduates who have participated in internships at our company are more stable, with a small turnover rate.
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?
We have 30 staff members in total. Of them, 25 studied T&C, and 5 studied science/engineering. Because of the nature of jobs in testing laboratories, high productivity is required in order to meet the short delivery times customers expect. We expect fresh

graduates to be well-equipped and ready to work without requiring a long training period. That is why we recruit more T&C graduates.
6) What are some of the job-specific competencies that you think new employees who are i) science or engineering graduates or ii) T&C graduates lack?
Due to the fast-changing technology and product development, to meet customer and legislative requirements for product safety, more and more new testing standards are being developed. From my point of view, both S&E graduates and T&C graduates have insufficient knowledge of new and emerging test standards because the standards they learned in university are not the most up-to-date test standards.
7) What do you think is the extent of the skills gap among the graduate employees?
Regarding S&E graduates, they do not have much knowledge of test standards. For example, graduates in electronic engineering discipline are strong in printed circuit-board design and mathematics. However, they may not possess knowledge of how to test electronic products to ensure compliance with the test standards of different regions (e.g., the UK, Japan). They require more time to learn different testing methods and test instruments through on-the-job training. Hence, they require more time to adapt to the environment in a testing laboratory. We require fast delivery times for our customers. S&E graduates are not skilful in handling test instruments, and they require a longer learning time to familiarize themselves with new test standards as compared to T&C graduates. T&C graduates can conduct new tests in a short lead time and be more productive.
8) How has the organisational culture hindered or supported the employees in terms of developing competencies and skills that match organisational needs?
Due to the fast-growing product development and rapid technological changes, product compliance is crucial and leads to a competitive business in the T&C industry. Short delivery times for testing services is our basic goal. Apart from our routine testing services and test reports, we also provide modification services to help customers identify problems, modify products and correcting errors. Graduates can have opportunities to learn more about our modification services such as failure analysis. Graduates who have worked at least two years in my company can get involved in modification services.
9) What are your views regarding the alignment of curricula with QF competency standards

for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?
I think that the alignment of curricula with QF competency standards is important to ensure that higher education institutes build up undergraduates in the correct direction and provide competent graduates to enter the T&C industry. The coverage of QF should clearly distinguish between hardline and softline toys in physical and mechanical tests.
10) What do you think about the depth of the work and the breadth of work? How much depth works best for skill development in the T&C industry? (Follow up question) What would you say about the depth of work and the breadth of work for i) science or engineering graduates and ii) T&C graduates?
If graduates are capable of providing breadth of work, they could easily find employment opportunities. I could assign different tasks to them. Personally, I have significant flexibility in terms of manpower allocation. For the graduates, they can determine their interests when they are exposed to different tasks. I think T&C graduates belong to this category. If graduates are capable of providing depth of work, they have fewer opportunities to work in other tasks and may not identify their interests. I think S&E graduates belong to this category. In my own case, I prefer staff capable of providing breadth of work because I can fully utilise the manpower resources to carry out more tasks.
11) What are your views regarding the curriculum design for i) science or engineering graduates and ii) T&C graduates?
Electrocompatibility (EMC) testing is vital for product compliance. However, I have observed that both S&E graduates and T&C graduates do not have much knowledge and are weak in this area, including the working principles and the test requirements. Hence, I would highly suggest increasing the coverage and strengthening undergraduates' knowledge of EMC testing.

Appendix V

Transcripts of the semi-structure interview for Participant C

Semi-structured interview questions
1) What are the entry requirements to apply for technical posts in your company?
I supervise a team of 44 engineers that provides mainly hardline testing services on products including toys, furniture, and household products. To be considered for the position of engineer, applicants must hold a degree with a major in science or engineering (S&E) subjects such as physics, product engineering, and testing and certification (T&C). We consider new graduates. We offer applicants who hold qualifications below degree level (e.g., higher diplomas) lower-level positions (e.g., assistant engineer).
2) What are the duties of the jobs? Do they meet your expectations?
Recent graduates' main duty is conducting tests, and each person focuses on a specific test first. Once they are familiar with the test, we assign them to conduct different tests under the supervision of team leaders. Once they are familiar with all the required tests, they can perform the tests independently. Because our samples are provided by customers in limited numbers and controlled quantities, and some of the samples are very expensive, we must ensure that the tests are performed correctly and the samples are utilised properly. Thus, when recent graduates conduct the tests, they are closely monitored by their supervisors to avoid errors. Because recent graduates lack experience, they seldom meet my expectations.
3) What do you think about the training that science and engineering students receive in higher education institutes? Are the academic subjects relevant to the market needs?
Generally, the training is relevant to job requirements and market needs. Because T&C is an extremely competitive industry, we must maintain high productivity and quality. T&C graduates easily meet these requirements. They usually demonstrate knowledge of different tests, and they quickly acquire the necessary skills to perform the tests. In other words, because T&C students learn a variety of test methods at university, we can shorten the lead time for training. This helps us to meet our production targets and deliver fast testing services to our customers. S&E graduates, on the other hand, have strong research and development skills, and they can explore and develop new services.

4) In terms of work readiness, are science and engineering graduates in the higher education institutions well-equipped to enter the T&C industry (e.g., do they meet the market needs or easily find employment opportunities)? If not, how can higher education institutions bridge this gap?
S&E graduates often lack knowledge of and experience with laboratory management, specifically equipment maintenance and calibration, and the ISO 17025 quality system, which is something I assumed they would learn at university. This is the most fundamental knowledge graduates should learn if they intend to work in testing laboratories. Hence, knowledge about and concepts in laboratory management should be strengthened for undergraduates.
5) What are your views regarding the competence of fresh-graduate employees in your organisation who have studied in science or engineering programmes or testing and certification programmes?
As mentioned previously, we are concerned about productivity. We must provide services with a short turn-around time. In light of these requirements, T&C graduates performed better than S&E graduates, as even recent graduates quickly learned different tests. Additionally, they can interpret test standards accurately and work out the tests. However, they are weak in failure and root cause analysis, which are skills students develop in subjects focused on research and development. In contrast, S&E graduates perform better than T&C graduates in exploring and developing new test methods, but recent S&E graduates have lower productivity. Consequently, S&E graduates with at least two years' experience working in testing labs are preferred to recent graduates.
6) What are some of the job-specific competencies that you think new employees who are (i) science or engineering graduates or (ii) T&C graduates lack?
The ISO 17025 laboratory management system is the most fundamental knowledge graduates should have, and they should know how to maintain adequate laboratory standards. Furthermore, ethics are essential to ensure impartiality is maintained. I know T&C graduates receive training on both these topics, but S&E graduates do not. Hence, I need to spend more time training S&E graduates.
7) What do you think is the extent of the skills gap among the graduate employees?

Because our testing instruments are commonly used and adopted in the T&C industry, they are considered industrial grade rather than laboratory grade. Thus, although S&E graduates are familiar with many testing instruments, some equipment is new to them, and they have to spend time learning about the equipment and understanding the working principles. T&C graduates are more suitable because they learn these working principles at universities. During job rotation, they quickly learn new tests and conduct tests with minimal supervision.
8) How has the organisational culture hindered or supported the employees in terms of developing competencies and skills that match organisational needs?
Performance is measured by team rather than individual, based on factors such as delivery time, number of jobs completed, and number of new customers secured. The factors used to measure performance differ from department to department due to the variations in the nature of the work. For example, performance in the chemical test department is measured based on outcomes instead of productivity, and success rates and customer satisfaction indexes are part of their measurement parameters. We clearly communicate our measurement parameters to our graduates from their first day to improve team performance and develop individuals' skills. For us, productivity is crucial. We have job rotation schemes to train graduates on multitasking, and graduates are closely mentored by their supervisors.
9) What are your views regarding the alignment of curricula with QF competency standards for the T&C industry? What do think about the coverage of QF competency standards in the curricula in higher education institutes?
May I ask what QF is? (I explained the details about QF to employer C and listed the 51 clusters of competence standards). I agree QF is useful, but I am not familiar with the QF standards.
10) What do you think about the depth of the work and the breadth of work? How much depth works best for skills development in the T&C industry? (Follow-up question) What would you say about the depth of work and the breadth of work for (i) science or engineering graduates and (ii) T&C graduates?
I definitely support breadth of work because my team's performance is measured by productivity. As mentioned, T&C graduates have knowledge of various tests and working

principles. This is very useful to our team.
11) What are your views regarding the curriculum design for (i) science or engineering graduates and (ii) T&C graduates?
Ultimately, from a commercial point of view, product recalls and product failure are our customers' main concerns. They need to ensure adequate quality to avoid product recalls and failure. That's why they send their products to us for testing. However, S&E and T&C graduates have insufficient knowledge in of these topics. Once again, their knowledge of laboratory management and quality management should be strengthened.