UNIVERSITY OF SOUTHAMPTON

Faculty of Humanities

Modern Languages and Linguistics

The Development of Critical Thinking Skills in Engineering Foundation Year: an exploratory study into theory and practice at UK universities.

DOI: 10.5258/SOTON/D1630

by

Sevendy Patchamuthu

Thesis for the degree of Doctor of Philosophy Applied Linguistics: ELT

November 2020

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

Faculty of Humanities

Modern Languages and Linguistics

Doctor of Philosophy

The Development of Critical Thinking Skills in Engineering Foundation Year: an exploratory study into theory and practice at UK universities.

by

Sevendy Patchamuthu

Critical thinking skills are regarded as one of the most highly valued skills for higher education. As such, critical thinking is acknowledged and widely accepted as one of the fundamental goals of tertiary education and a defining concept of graduate education. Therefore, developing students in critical thinking skills has paramount importance as an aid in cultivating personal and professional intellectual traits for students. However, recent discussion and research on critical thinking development show there is little empirical research on foundation and undergraduate courses. Besides that, research conducted on critical thinking skills lacks variation in research design, since many studies on students' development in critical thinking skills mainly used single instrument quantitative methods, for example self-report surveys, to measure their classroom experience. Similarly, critical thinking research on assessment is also noted to have employed a single quantitative tool. This thesis argues that using a single method or quantitative method does not provide a full picture of critical thinking skills development among students, therefore there is a need for an in-depth discussion using qualitative methods for a better understanding of the issue. Hence, this research employed a mixed-method approach to explore the theory, practice and development of critical thinking skills within engineering foundation year programmes in the UK.

The development of critical thinking skills among engineering foundation year students was investigated firstly, by analysing three selected critical thinking models relevant to the engineering syllabus; Dewey's Critical Analytical Model, (1910 and 1933), Paul, Niewoehner and Elder, (2006) and the Conceive Design Implement Operate (CDIO) Critical Thinking Model, (2011). Secondly, both students and module instructors were interviewed, the students at three different stages of their study over a period of a year, followed by the module instructors. Document analysis was also conducted on the programme specifications of all the modules taught in the programme, which were then checked against the interview reports to find out to what extent they aligned with the teaching and learning process in critical thinking and the development of critical thinking skills as reported by the students.

The findings showed there is an alignment between the students' perception, understanding and the development of critical thinking skills with the aims and the learning outcomes of the programme syllabus. However, the analysis of module instructors' interview shows there is a slight divergence of views with students' on critical thinking skills and their development at engineering foundation level, and a debate on how far the module instructors should go when choosing between the subject matter and the critical thinking skills at the foundation level of engineering study.

FACULTY OF HUMANITIES

Modern Languages and Linguistics

Doctor of Philosophy

THE DEVELOPMENT OF CRITICAL THINKING SKILLS IN ENGINEERING FOUNDATION YEAR: AN EXPLORATORY STUDY INTO THEORY AND PRACTICE AT UK UNIVERSITIES

Sevendy Patchamuthu

Table of Contents

Table of Tables

Table of Figures

Academic Thesis: Declaration of Authorship

I, Sevendy Patchamuthu, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

The Development of Critical Thinking Skills in Engineering Foundation Year: an exploratory study into theory and practice in two UK universities.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signed: Sevendy

Date: 12 November 2020

Acknowledgements

My study journey has been quite challenging since the start of my quest for knowledge on critical thinking, from the start of my theoretical inquiry to the end of empirical work, which has been a trying time for patience and perseverance. The journey, however has taught me the value of courage, and believe in what I do.

Two roads diverged in a wood, and I—

I took the one less traveled by,

And that has made all the difference (Robert Frost, 1916)

This PhD would not have been possible without the personal and expertise support of my supervisors. I owe them my deepest gratitude and thanks for their patience and kind considerations supervising my research. I am grateful to Dr Ying Zheng and Professor Rosamond Mitchell (Department of Modern Languages), Dr Su White (Faculty of Engineering), and my former supervisor, Mr Chris Sinclair for their encouragement, patience, and their cheerful dispositions, which made my PhD an invaluable experience.

My utmost appreciation and gratitude goes especially to Professor Rosamond Mitchell, an expert in critical thinking research for offering her expertise and navigating me to the right direction. Her guidance has given me confidence, and taught me to be strong facing my academic life.

My special thanks also goes to the University of Southampton library staff for assisting me with the inter-library loans, computer service line, especially Jonathan Lightfoot and Dean Wall, the security officers at the Avenue Campus, whom made me feel safe, as I am often the last to leave the campus. My PhD colleagues, Theya, Wara, Miaw, Kayoko, Coralie and Phuong, who had been there in supporting and motivating me during my difficult times.

Last, but not least my heartfelt gratitude and thanks to my wonderful family, my son, Gurupharan, and daughter Jananie for their patience and understanding when they lack my attention while I was working on my thesis. Finally, I dedicate this PhD to my Mum Papathy and Dad Patchamuthu, and my elder brother Mathi for instilling the value of education, and providing me with the opportunity to pursue my dream.

Definitions and Abbreviations

A1	Maintain and extend a sound theoretical approach to the application of technology in engineering practice.
A2	Use a sound evidence-based approach to problem solving and contribute to continuous improvement.
ABET	Accreditation Board for Engineering and Technology - USA
ACAT	Analysis of a Complete Act of Thought (ACAT)
AHEP	Accreditation of Higher Education Programmes for Engineering Council UK
B1	Identify, review and select techniques, procedures and methods to undertake engineering tasks.
B2	Contribute to the design and development of engineering solutions.
BEng	Bachelor of Engineering
BTEC	Business Technology Education Council
C2	Manage tasks, people and resources to plan and budget.
CAIB	Columbia Accident Investigation Board
CBI	Content-based Instruction
CCTDI	California Critical Thinking Dispositions Inventory
CDIO	Conceive Design Implement Operate
CEAB	Canadian Engineering and Accreditation Board
CTs	Critical Thinking Skills
CW	Coursework
DLC	Dewey’s Logical Considerations
EAP	English for Academic Purposes
ESAP	English for Specific Academic Purposes

Definitions and Abbreviations

ECE	Electrical and Computer Engineering
EE	Electricity and Electronics
EES	English for Engineers and Scientists
EFL	English as Foreign Language
EFY	Engineering Foundation Year
EP	Engineering Principles
ESL	English as a Second Language
ESP	English for Specific Purposes
ESAP	English for Specific Academic Purposes
ET	Electrical Technology
EUR-ACE	European Accreditation
FY	Foundation Year - a one year preparatory programme to prepare students without the traditional and entry qualifications of A-Levels in mathematics and physics for entry to UK engineering degree programme
IELTS	International English Language Test System
IMT	Introductory Engineering Mathematics
IT	Information Technology
JIF	Judgement: Interpretation of Facts
KTH	Kungliga Tekniska Hogskolan
L1	First Language
L2	Second Language
MCU	Meaning: Conceptions and Understanding
MEng	Master of Engineering
MIT	Massachusetts Institute of Technology
MS	Mechanical Science

MT	Mathematics
MTA	Mathematics A
MTB	Mathematics B
NASA	National Aeronautics and Space Administration
NVivo Pro	Qualitative data analysis computer software package produced by QSR International (software developer)
Pathway Programme	A preparatory course to prepare students for undergraduate admission through foundation year programme; for international students language course is incorporated
PGTA	Post Graduate Teaching Assistant
PNE	Paul, Niewoehner and Elder Engineering Reasoning Model
PROJ	Project
PSI	Problem Solving Inventory
PWA	Language Pathway A
PWB	Language Pathway B
RTS	Routes to Success
S1	Demonstrate basic competence in mathematical modelling of simple engineering systems.
SBS	Subject Benchmark Statement (Engineering)
SCS	Study and Communication Skills
SIID	Systematic Inference: Induction and Deduction
STATS	Statistics
TACES	Thought: Abstract, Concrete, Empirical and Scientific
UK-SPEC	The UK Standard for Professional Engineering Competence

Chapter 1 Introduction

Critical thinking is a graduate attribute, which students are expected to learn and acquire as a process of university education. Due to globalisation of the economy and advance in science and digital technology, employers in the recent times are seeking more for graduates who are not just competent in the subject matter, rather with intellectual traits such as critical thinking skills for an efficient employee with good independent thinking skills, problem solving, decision making and others, (Behar-Horenstein and Niu, 2011; Kirn and Benson, 2018). Recognising their enduring importance, many advanced countries including the UK have listed critical thinking skills as key educational objectives, and this in recent times has been adopted by many other countries across the world, (Goh, 1997; Aida Suraya, *et al*., 2005; Li and Liu, 2006; Tan, 2017). Hence, critical thinking skills should be central to curriculum design and classroom instruction, to promote and develop these skills among students, (Rudd, Baker and Hoover, 2000; Bailin and Siegel, 2003; Smith, 2003; Elder, 2005: 39; Halx and Reybold, 2005; Arum and Roksa, 2011; Hammersley-Fletcher and Hanley, 2016; McPeck, 2016). Despite the fact that, it has been agreed that critical thinking skills are of paramount importance, however, there is very little empirical evidence that students actually learn and develop critical thinking skills substantially in their undergraduate programme.

The actual situation of students' development of critical thinking in their undergraduate programme is not much known because the majority of empirical research, either has been focused on analysing documents, or assessing students' abstract critical thinking dispositions using a quantitative approach, for example, critical thinking assessments, student self-report surveys outside classroom,(Tsui, 2001; 2002), or instructors' observation, (Ellwood and Nakana, 2009; Lun, Fischer and Ward, 2010; de Jager, 2012) with little in-depth investigation of students' actual critical thinking development through classroom practice, (Browne and Freeman, 2000; Brumfit, *et al*., 2005; Johnston, *et al*., 2011). There are also further arguments by some critical thinking researchers (Braun, 2004; Papadopoulos, Rahman and Bostwick, 2006; Douglas, 2012), that students' development in these skills has not been addressed sufficiently by taking account of students' views and learning experiences directly.

This study is focused on how Engineering Foundation Year (EFY) students develop critical thinking skills (CTs) in their foundation programme. Recognising the importance of students' critical thinking development, there is a need to find out how students develop these skills, whether educational practices affect students' ability to think critically, and finally, how far higher education promotes critical thinking. To investigate this, existing theories of critical thinking skills, students' understanding of the skills, and lecturers' approach in providing practice for students to develop the skills are analysed in the study reported in this thesis.

1.1 Critical Thinking Skills for Engineering Foundation Year: Motivation for the Study

Critical thinking is about rational thinking which draws conclusions from facts and evidence, analysing and evaluating one's own, and other people's reasoning with the effective use of language with clarity and discrimination, (Thomson, 2009: 2). Critical Thinking skills are vital for engineering courses as they play an integral part in discipline-based tasks, for example creating scientific talent to undertake the challenging process of critical thought and critical reasoning in solving engineering problems, (Fleming, Garcia and Morning, 1995: 437; Pariser, 2001; Kroes, 2015). Paul, Niewoehner and Elder, (2006) and Godfrey and Parker, (2010) also assert that it is essential for engineering students to have developed these skills in order to improve their competitiveness in the engineering field and global economy. Therefore, it is important to find out the state of students' pre-existing knowledge of critical thinking skills, and how this knowledge can be developed with effective critical thinking instruction with the support of existing theory on critical thinking skills for engineering studies.

1.2 Scope of the Study

The main purpose of the study is to find out how EFY students develop critical thinking skills within this one year preparatory programme before they progress to their destination degree course. The empirical study focused on EFY of cohort year 2014-15 of two UK universities which run a similar foundation year programme. The study aimed to identify what are the actual critical thinking skills required in the engineering context and the process involved in learning and acquiring the skills. This is established in two ways, firstly, by a critical review of the existing literature on critical thinking skills including philosophical approaches and critical thinking in subject-specific fields. The research then conceptualised the framework for critical thinking skills for engineering based on three critical thinking models; Dewey's Logical Considerations, (Dewey, 1910), Paul, Niewoehner and Elder Engineering Reasoning Model (Paul, Niewoehner and Elder 2006), and the Conceive Design Implement Operate (CDIO) Syllabus, v2.0 (Crawley, *et al*., 2011). Secondly, through empirical work, data was generated from student and module instructor interviews, and document analysis for all the modules offered in the EFY programme.

In the light of the literature reviewed and findings of the empirical work the research attempted to identify the types of critical thinking skills for engineering in general, and specifically for EFY which will be recommended for research investigations in the future.

1.3 Problem Statement

Research on students' development of critical thinking skills within undergraduate programmes and more so within foundation years, is limited. Past critical thinking development research has mainly focused on academic writing, (Pally, 2001; Johnston, *et al*., 2011), and instructors' observations of students' classroom participation, (Melles, 2003; 2008). Up to-date there is very little empirical research on criticality development across higher education curriculum in the actual undergraduate classroom, (Halpern, 1999: 69; Browne and Freeman, 2000; Johnston *et al*., 2011). In addition, Tsui, (2002), Clarke and Garbet, (2004) and Brumfit, *et al*., (2005: 146) question how far higher education systems need or are willing to promote and cultivate the expected types of criticality.

Syllabuses such as Subject Benchmark Statements, UK, (Engineering), (2015), and the widely used undergraduate engineering syllabus, Conceive Design Implement Operate (CDIO) Syllabus v2.0, (Crawley, *et al*., 2011), for Engineering education have outlined the importance of critical thinking skills in underpinning academic practice. However, with very little empirical research on the improvement or development of students' critical thinking skills in undergraduate classrooms it is difficult to establish concretely whether students have actually acquired the skills supported by current curricula. Therefore, to fill the gap in the literature this study aimed to investigate how students develop their critical thinking skills supported by the Engineering Foundation Year (EFY) programme. In order to conduct an in-depth investigation a qualitative approach was adopted.

This study involved participants from engineering foundation year with a main focus on students' development in critical thinking skills. This is explored by looking at theory and practice within the engineering foundation year. Therefore, to conduct the research, the key terms, *development, theory* and *practice* need to be defined within the context of the Foundation Year (FY) and engineering education. The terms used are limited to the boundary of the setting and participants involved in the study. For the purpose of this study, *development* refers to students' changing ability to identify critical thinking skills and apply them accordingly in their engineering study. The term *development* also refers to the mastering of some of the basic intellectual traits required for engineering professionals in their foundation year progressing to their bachelor's degree. Students' *development* in critical thinking in this context is the progress that students made to become a *good thinker* through their academic experiences in the FY. The *theory* refers to the literature on conceptualisation of critical thinking skills through general philosophical and subject-specific approaches to engineering education. *Practice* refers to the teaching and learning activities provided by the module instructors grounded in their pedagogical philosophies and curriculum designed for the engineering foundation programme.

1.4 Research Aims and Research Questions

The aim of the research is to investigate and understand the nature and development of both general and subject specific critical thinking skills for engineering education. This is done by looking at how the current curriculum and practice within the Engineering Foundation Year (EFY) programme address the expectations and learning needs of foundation engineering students to develop the skills.

1.4.1 Research Aims

The following research aims guided the study:

I. To investigate Engineering Foundation Year (EFY) students' understanding and attitudes towards critical thinking skills at the beginning and at the end of the programme, taking account of their previous learning experiences, and their language cultural background at the beginning and end of the programme. (Research Questions: 1; 4; 5)

II. To investigate the relationship between teaching and learning practice within the foundation year programme, and the development of critical thinking skills among students. (Research Question: 2)

III. To find out lecturers' perception of critical thinking skills for engineering based on module instructors' definition of critical thinking skills and on analysis of foundation year course documents. (Research Question: 3)

IV. To design a blended conceptual framework for critical thinking for Engineering Foundation Year (EFY).

1.4.2 Research Questions

The research is further guided by the following research questions:

1) What are Engineering Foundation Year (EFY) students' perceptions and attitudes towards critical thinking skills at the beginning and at the end of the programme?

2) How do students learn and develop their critical thinking skills in the Engineering Foundation Year programme?
    a) To what extent do students have the opportunity to practise critical thinking skills in the Engineering Foundation Year programme?
    b) What types of critical thinking skills are students exposed to during the foundation year?
    c) To what extent does students' prior learning influence their ability to learn and apply the skills in their foundation engineering study?
3) What is faculty's (lecturers') goal for students' critical thinking skills?
    a) Are critical thinking skills evident in general curricula for the discipline of engineering foundation year, and in module profiles and other documents? If yes, what types of skills are given preference?
    b) How do the foundation year module instructors define critical thinking skills and how does this influence their pedagogical choices?
4) Does a student's cultural background affect his/her ability to learn and apply critical thinking skills?
5) To what extent does language play a role for students in learning and applying critical thinking skills?

1.5 Conclusion

The purpose of the study is to understand the nature of the general and subject critical thinking skills associated with engineering education. To investigate this, the following a literature review (Chapter 2), the study developed an overall theoretical framework for critical thinking skills (CTs) in engineering, bringing together a general philosophical approach (Dewey, 1910) with proposals from engineering educators (Chapter 3). The empirical study (Chapter 5, Chapter 6 and Chapter 7) adopted a qualitative approach to explore the phenomenon by firstly, looking at EFY students' changing perceptions and understanding of critical thinking skills based on their learning experiences in the EFY programme. Module instructors' conceptions of critical thinking were also investigated, as research on critical thinking instruction suggests that educators' definitions of critical thinking could have direct impact on their pedagogical choices which could in turn affect students' development of the skills. Educational practice is further investigated through analysis of course documents from the EFY programme.

Chapter 2 Review of Literature

2.1 Critical Thinking in Higher Learning Institution

Higher learning institutions in western education and elsewhere have long claimed that a fundamental goal of tertiary education is to promote Critical Thinking skills (CTs) and support students to develop these skills. However, Gellin, (2003: 746), claims that the inclusion of CTs into the university curriculum, took place slowly. Most universities did not readily accept and implement explicit teaching of the skills, though they were introduced, and much discussed in the field of education in the early twentieth century. Gellin, (2003: 746), further argues that CTs teaching was adopted only gradually, for example, the introduction of CTs was initiated by Sumner in 1906 at Yale University, and then followed by Dewey in 1910 at Columbia University. Geilin further claimed that it took another 50 years for their recognition as a general goal for higher education in the 1960's.

Nussbaum, (1997) cited in Johnston *et al*., (2011: 16), argues that earlier traditions of liberal education in the western universities followed the traditional Anglo-Saxon liberal position which largely did not focus on instructional critical thinking, rather on educating *a small governing elite.* As such, it could be perceived that the resistance in applying the CTs in teaching and learning activities at higher learning institutions at this period of time may be due to lack of expertise in the field. Or, the academics may not have fully conceptualised these intellectual traits which in the past were valued within a small elite community of scientists and scholars and were not largely passed down to a bigger population of students of diverse background at universities.

Nevertheless, the beginning of the 1960's saw a transformation in the higher learning institution whereby, CTs took a centre stage as the most important skills students should develop within a discipline and important for advancing knowledge, (Gellin, 2003). Since then, there has been a rapid integration of CTs into higher education which largely took place in western universities. Although faculty and universities were fully supportive of the move, there is evidence that educators were not fully trained to teach these skills, according to Clarke and Gabert, (2004: 31) and Halx and Reybold, (2005). Clarke and Gabert, (2004) further claim that in some cases this resulted in students becoming a part of a pedagogical adventure and experiment in implementation with little assurance students were actually developing these required skills. This lack of systematic implementation is claimed by them to have continued in recent years at most universities, affecting students' ability in CTs particularly in their undergraduate studies. Indeed, it has been argued students' success at university is largely pre-determined by the level of criticality they bring with them from their previous learning experience, (Chapple and Curtis, 2000; Alexander, Argent and Spencer, 2008; Moore, 2011).

Today, however, critical thinking is also known to be an employability skill most favoured by employers of graduate students as this could help them to face a globalised world which has become more competitive due to constant change and an in-flux of new information and technologies. Hence, current commentators reinforce that developing CTs among students should be the guiding force for educational efforts, (Pithers and Soden, 2000; Rudd, Baker and Hoover, 2000; Smith, 2003; Elder, 2005: 39; Arum and Roksa, 2011; McPeck, 2016). This could be achieved by promoting and developing CTs among students through effective educational curricula, pedagogy and policy. However, achieving this could be challenging due to some contributing factors such as inadequate instructional practice in critical thinking.

There could be various contributing factors to the barriers in adopting and implementing critical thinking as instructional practice which need more investigation. These are discussed in the following literature review sections, which fall into two broad groups. The first group (sections 2.1 -2.6) examines the emerging place of critical thinking in higher education, plus empirical research on its attempted implementation in different disciplines. The second group (2.7-2.9) examines the philosophical origins of critical thinking more closely, focusing in particular on the work of John Dewey. Together these sections lay the groundwork for the theoretical framework which underpins the whole study, which is presented in Chapter 3. In more detail, the sections are as follows: looking at critical thinking instruction and educators (2.2), culture and critical thinking (2.3), academic English and critical thinking (2.4), critical thinking across disciplines (2.5), engineering education and critical thinking, (2.6). Then, the conception of critical thinking is discussed, next, is defining critical thinking (2.7). This is followed by Dewey's reflective thinking and its relevance to engineering study (2.8), and finally, the concept of 'critical being' is discussed (2.9).

2.2 Critical Thinking Instruction and Educators

Higher education has acknowledged and widely accepted critical thinking as one of the fundamental educational ideas. However, Paul, Elder and Bartell, (1997); Ahern, *et al*., (2012) and Ralston and Bays, (2015) claim some faculty in higher education lack any substantive concept of critical thinking. Woodward-Kron, (2002); Paul, (2005) and Moore, (2013), also argue that faculty do not realise they have an inadequate understanding of the concepts, instead believing they have comprehensive understanding of the skills and are successfully teaching them to students.

However, in a non-Western setting, Aliakbari and Sadeghdaghighi, (2012), surveyed 100 English teachers in Iran on their perceptions of the barriers to CTs. The majority of them admitted, that they were not sure of their ability or felt unprepared to teach or demonstrate the skills. From the sample, 60 % disagreed that critical thinking should be the primary teaching objectives, while 81% claimed their administration did not provide sufficient support for professional training for teaching CTs. This is in agreement with the claim of Tsui, (2001: 22), that many faculty members avoided teaching CTs unless they were confident that students were already prepared to exercise this higher-order thinking skill. However, the instructors' assumption that students are not ready for learning CTs is mostly not confirmed by any empirical research on students' readiness in the skills. Tsui, (2002) and Landsman and Gorski, (2007), claim that this instructional confusion has resulted in students being mostly not taught these thinking skills explicitly, depriving them of years of needed training. This is because critical thinking is not an innate ability, but needs to be taught through expert input and feedback, (Siegel, 1999; Facione, 2000; McBride, Xiang and Wittenburg, 2002; Chan and Yan, 2007).

Students and instructors or academics require institutional space in which critical thinking practice can flourish. Thus, faculty attitudes are important to the development of students' CTs. Based on four institutional case studies, Tsui, (2001), investigated the relationship between pedagogy and critical thinking development with data gathered from interviews with professors and students, and from classroom observations. The findings show that students' success in developing their CTs relies heavily upon faculty commitment and enthusiasm for teaching the skills. Similarly, Pascarella and Terenzini, (1991) and Pascarella, (1997) believe students experiences create greater cognitive gains, if they perceive faculty as being concerned with teaching and students' development in these skills. Some recent empirical research by Phillips and Bond, (2004); Chan and Yan, (2007); Abrami*, et al.*, (2008); Cheah, (2011), Heijltjes, Leppink and Paas, (2014) support the idea that explicit teaching by faculty leads to better learning and development of CTs.

On the other hand, Paul, (2005: 8) claims educators expect students to engage in analysis but have no idea of analysis criteria or how to teach them to students. It is further claimed that educators want students to use intellectual standards in their thinking but have no clear conception of what standards they are expected to use or how to explain them. In research conducted by Paul, Elder and Bartell, (1997), 38 public and 28 private colleges and universities were selected to answer the question, *to what extent are faculty teaching for critical thinking*? The responses indicated that, faculty members reduced the concept of critical thinking to, *constructivism, Bloom's Taxonomy, process based learning, inquiry based* learning with little mention of intellectual traits like *intellectual integrity, intellectual humility, fair-mindedness, and* *intellectual perseverance, confidence in reason, intellectual courage, intellectual empathy and intellectual autonomy*. Of the 66 colleges and universities investigated, 89% claimed critical thinking is a primary objective of educational instruction, but only 19% could give clear explanation of what critical thinking is. From the observations, only 9% of the teachers were actually providing practice for critical thinking in the class. 73% claimed it is challenging to teach students CTs because students have inadequate skills to assess their own work, however, only 8% of the educators could clearly explain what standards were.

Based on these research findings, Paul, Elder and Bartell, 1997 and Paul, and Elder, 2009 further argued that, teaching CTs in general study skills within general study skills programme, which are usually run by Philosophy or English departments will not work either, as such programmes do not teach students how to analyse thinking using intellectual traits or teach them how to think within their disciplines. For example, English classes may teach persuasive writing, and engineering instructors may ask how this can help in report writing. Therefore, teaching of CTs needs to be based on specific intellectual traits or elements of reasoning and through modelling by discipline-based teachers to help students to develop the skills through structured practice within their discipline.

This section has reviewed evidence on the inadequate attention often paid to critical thinking in higher education pedagogy and has identified the need for discipline-focused education in critical thinking. In the next section we examine further issues surrounding the teaching and learning of critical thinking skills connected with the characteristics of different student groups, especially the complexities involving previous learning experiences, academic culture, and academic language, and how these may affect students' acquisition of critical thinking skills.

2.3 Culture and Critical Thinking

In recent years, many academic research papers have suggested that students differ in their thinking styles due to their cultural background. In most cases, the differences are seen as involving deficits rather than diversity in thinking among students from across the globe. In such publications on critical thinking, culture and students' academic performance in higher learning institutions, especially in the western universities, students from non-western cultures are described as having inadequate CTs as compared to the mainstream students, (Egege and Kutieleh, 2004a; 2004b; Evers, 2007; Durkin, 2008). However, Paton, (2005) argues that, learning and applying critical skills in academic context needs time and training for students to get adjusted to the new academic culture. Paton further argues that this is not just an overseas students' problem but of university students in general. In most cases, overseas students enrolled in short university programmes which did not provide the space to demonstrate their CTs more explicitly, therefore, in such cases students' backgrounds have no direct influence on their performance in the skills.

These arguments are largely based on stereotypes regarding students' thinking styles and their traditional culture. Students' thinking styles could be attributed to individuals' origins and cultures. In most cases, individuals or students from western academic background are viewed as more analytical and critical compared to individuals from other parts of the world, especially East-Asian students who are viewed as more holistic thinkers, (Nisbett, 2003; Cuypers, 2004: 75; Jen and Lien, 2010). Cuypers, (2004: 75) explains, in contrast to *primitive culture* or *theocratic culture*, that the western liberal democracy places a very high value on rationality and critical thinking, and claims that students from non-western traditions struggle to learn and apply the critical thinking skills. For example, McBride, Xiang and Wittenburg, (2002) researched students from western culture and mainland China by comparing the dispositions towards critical thinking. The findings showed that students from American culture (individualistic) outperformed Chinese (collectivistic) with respect to maturity and self-confidence, and this was interpreted as reflecting greater critical thinking among the 'individualistic' group.

In particular it has been argued that cultures which are rooted in traditional social practice, like in conforming to social harmony and deference to elders and teachers, may hinder the acquisition of critical thinking skills. Barnawi, (2011: 195) conducted research in the college English as a Foreign Language (EFL) writing classroom to incorporate critical thinking, and found it was challenging for both the teacher and the students to implement and learn the notions of critical thinking and self-voice due to the academic culture of the classroom, where the teacher, 'dominates the students' thinking process by imposing his or her ideas. On the other hand, the students believe and trust the knowledge transmitted by their teachers, and therefore, may reject the notion of critical thinking and self-voice. Many Asian cultures like the Middle East, (Sert, 2006), China, (Liu, 2005), and Japan, (Stapleton, 2001) value authority, conformity and respect for elders and teachers, and therefore, any thinking practice which contradicts these may be opposed. Nevertheless, the repeated findings that students lack CTs due to their heritage culture and previous learning background lack clear evidence to support this claim more objectively, (Lun, Fischer, and Ward, (2010); Chan, Ho and Ku, 2011)

Hence, this issue needs to be explored further with a more holistic qualitative research looking at other possible contributing factors such as, age, gender, socio-economic and others for a more conclusive empirical support. Furthermore, there is a need to define *culture* in that context of argument before making a general claim on its role in critical thinking. Taking this into consideration, the present research put more focus on other contributing factors to conduct a more comprehensive investigation on this issue.

2.4 Academic English and Critical Thinking

As we have just seen, the role of culture in possible resistance to critical thought has been widely debated among scholars in education and English Language study. Students entering English medium education for example need to have the ability to think both critically and objectively to support or challenge an issue or idea and express themselves effectively through the medium of English, (Alexander, Argent and Spencer, 2008). However, some non-native students of English have been claimed to possess very little, or none of the CTs required because of the very limited exposure to this type of thinking skills in their schooling, (Nisbett, 2003; Jen and Lien, 2010). There are several research publications in English language teaching which claim that some non-native students lack CTs in various academic contexts, (Andreas, 2005; Abd. Rashid, Chew and Kabilan , 2006; Durkin, 2008; Emir, 2009; Lun, Fischer and Ward, 2010; Mok, 2010.). The deficit is said to be mainly reflected in their academic writing, for example, critical article reviews, literature reviews, and dissertations, but also in oral presentations and involvement in class room debates.

Melles, (2003; 2008: 23), investigated the classroom participation of international students in English medium education; Chinese, Japanese, Thai, Latin American and Middle Eastern and claims that as well as coming with limited English proficiency, they may also have not acquired CTs due to limited exposure to these skills in their *prior learning*. This is also supported by Abd. Rashid, Chew and Kabilan, (2006: 21) cited in Patchamuthu, (2010) in the context of an English reading class in Malaysia, in which not much priority was given to meta-cognitive reading strategies to facilitate critical analysis in the language classroom. These studies suggest that most English as a Second Language (ESL) or English as a Foreign Language (EFL) classrooms do not give priority to critical analysis at a very early age of language learning, therefore, students' could find it quite challenging to apply the skills when they move on to tertiary education with English medium instruction.

There are many factors contributing to why some non-native students in English medium instruction have difficulty with CTs and understanding certain concepts employed by western academia. Some students have difficulty conceptualising CTs because they have not been exposed to critical analysis in the language class due to traditional teacher centred practice and government control for political reasons, (Kubota, 1999; Dong, 2006; Alnofaie, 2013). Or, this may be due to some language teachers' perception that students need high level language proficiency in order to be critical thinkers, and as such do not provide opportunities for students to practise and to acquire CTs in the classroom setting at lower levels, (Cheng, 2006; Mok, 2010).

However, there is very limited empirical research which has investigated the relationship between language and CTs among non-native students in English medium instruction. Also needed are comparative studies which look into the similarity and difference between native and non-native students' use of language and critical thinking skills in their domain field or discipline. Pally, (2001), investigated the issue of CTs and language being taught in combination through content-based instruction (CBI) using case studies, with 13 students from America, Africa, Asia and Europe in eight classes from fourth year at two institutions. Students' summary writing was assessed, and essays are compared between advanced students who had not had sustained content study and lower level students who had. The findings show that both groups of students had difficulties in analysing texts, so as to identify main ideas and supporting details. However, the lower level students who had experienced sustained CBI showed stronger critical analysis skills compared to the advanced level students who did not. Pally (2001), asserts that, studying through CBI in a discipline over time, including undertaking critical reading on familiar content, provides substantial information for students to analyse and write. Pally, (2001: 295) dismisses the idea that explicit teaching of critical thinking promotes critical thinking, but rather, supports democratising it by providing students the opportunity to practice the skills through discovery learning. Pally, (2001: 284) further argues that, good command of English lexis or syntax, while important, is not necessary to produce a good argument.

Argumentation theorists point out that language plays a vital role in critical thinking, for it is needed to explain, argue, and reason with clarity and precision, (Siegel, 1999). To produce a good argument, students need to understand the central issue of a problem or a claim. Appropriate language use is also needed to explain or to produce a valid reason, while, wrong word choice, or emotive, non-academic language style could be a barrier in applying critical thinking effectively. This argument supports the findings of Liaw, (2007), that critical thinking improves language proficiency. According to Chamot, (1995); Chapple and Curtis, (2000); Shirkani and Fahim, (2011: 112), CTs are learnt effectively along with foreign language. However, Alagozlu and Suzer, (2010: 785) explored critical thinking levels of Turkish pre-service teachers of English on writing tasks both in first language (L1) (Turkish) and second language (L2) (English) focusing on language production and concluded on the basis of their findings, that language is not a barrier in critical thinking. The findings show there is no statistically significant relationship between the two, which suggests that respondents have transferred their thinking habits in their mother tongue to English essays.

In contrast to the above, Miekley, (2014), asserts that high order thinking skills in English medium instruction clearly demands high level language proficiency based on research conducted among non-traditional pre-graduate English as a Second Language (ESL) students at a community college in the U.S. The students were from Mexico, Russia, Bulgaria, South Korea, Egypt and Romania, and data was collected through students' written feedback and personal notes. Students were exposed to critical analysis in the language classroom through spoken activities at the beginning of the course and their first feedback was collected. The rest of the sessions continued to highlight critical thinking in the language classroom. Final feedback was collected at the end of the course to determine if students had improved their capability for critical analysis. Miekley, (2014), found that students with low level language proficiency had problems expressing their views in written work, which he interpreted as showing that deficiency in the target language could be a barrier to learning and acquiring CTs.

2.5 Critical Thinking across Disciplines

Thinking or reasoning about any subject is largely reliant upon several forms of knowledge about the content or subject-matter. Cognitive researchers and those adopting field-specific approaches to learning and thinking have emphasised the importance of content in experiential knowledge and procedural knowledge in the performance of tasks, (Kurfiss, 1988; Johnston, *et al.*, 2011). Many critical thinking scholars claim background knowledge in a particular knowledge domain is a precondition for any critical analysis to take place, (Bailin*, et al*., 1999). Hence, CTs which are focused on discipline-based thinking could be more beneficial for students than general skills. To illustrate disciplinary discussions, the areas of Sociology, Medicine, Nursing, and Business will be analysed on how these different disciplines apply CTs.

The area of Sociology requires students to apply CTs to identify surrounding social issues, think more critically about the phenomenon and be able to apply the outcomes in the real world in an attempt to solve the problem. Rickles*, et al*., (2013), conducted research in a Sociology class by assessing students' written work and observing classroom discussion. Students' written work was assessed based on three different scores; critical thinking scores, accurate use of sociology ideas and writing quality. The intervention was shown to have a significant impact on students' performance in discipline-specific (Sociology) critical thinking skills. The findings suggest that, students have a better grasp of how to apply the CTs, if the teaching was based on 'modelling' CT by the tutors.

On the other hand, Business courses were more focused on strong analytical, problem solving, persuasive, rhetorical negotiating skills and teamwork, to initiate students to the real business world, (Zhu, 2004; Phillips and Bond, 2004; Dwyer, Jenkins, 2010; Boswell and Elliot, 2015). Zhu, (2004), conducted a literature review of 95 course syllabi and students' handouts on writing assignment from undergraduate and graduate students from different departments within Business; Management, Marketing, Economics, Accounts, Finance and Information System programmes. The findings claim that though all the departments are dedicated to business studies, they may not constitute a unified discourse community because of their differing goals.

In Medicine and Nursing, however, CTs are required in helping students to manage complex health situations and to deal with patients effectively according to Salsali, Tajvidi and Ghiyasvandian, (2013). In both Nursing and Medical courses, students are expected to be reflective thinkers and produce reflective reports to monitor their commitments in handling patients and the environment they are in. For such contexts, critical thinking is not based solely on sound reasoning, but more on moral perspectives motivated by a care for a more humane world. Medical students are therefore, exposed to CTs through experiential learning intended to train students for clinical problem solving, (Maudsley and Strivens, 2000).

Although, all graduate students are expected to learn and acquire CTs, the ultimate goal of higher learning institutions in this context is to create high level thinking and ethical thinking students not only for supply and demand for the job market, but to prepare them for the challenging globalised world and to become morally valuable world citizens.

2.6 Engineering Education and Critical Thinking

Engineering innovation has played a fundamental role in addressing basic human, social and economic needs, poverty reduction, and sustainable development. In a broader context, the history of engineering and innovation is connected to the history of social and economic relations. For example, Marjoram, (2010: 30 cited in UNESCO Report, 2010) claims that at each stage of the time of 'Stone Age, Bronze Age, Iron Age, Steam Age and Information Age', engineers have contributed greatly in shaping human interaction with the world socially and economically.

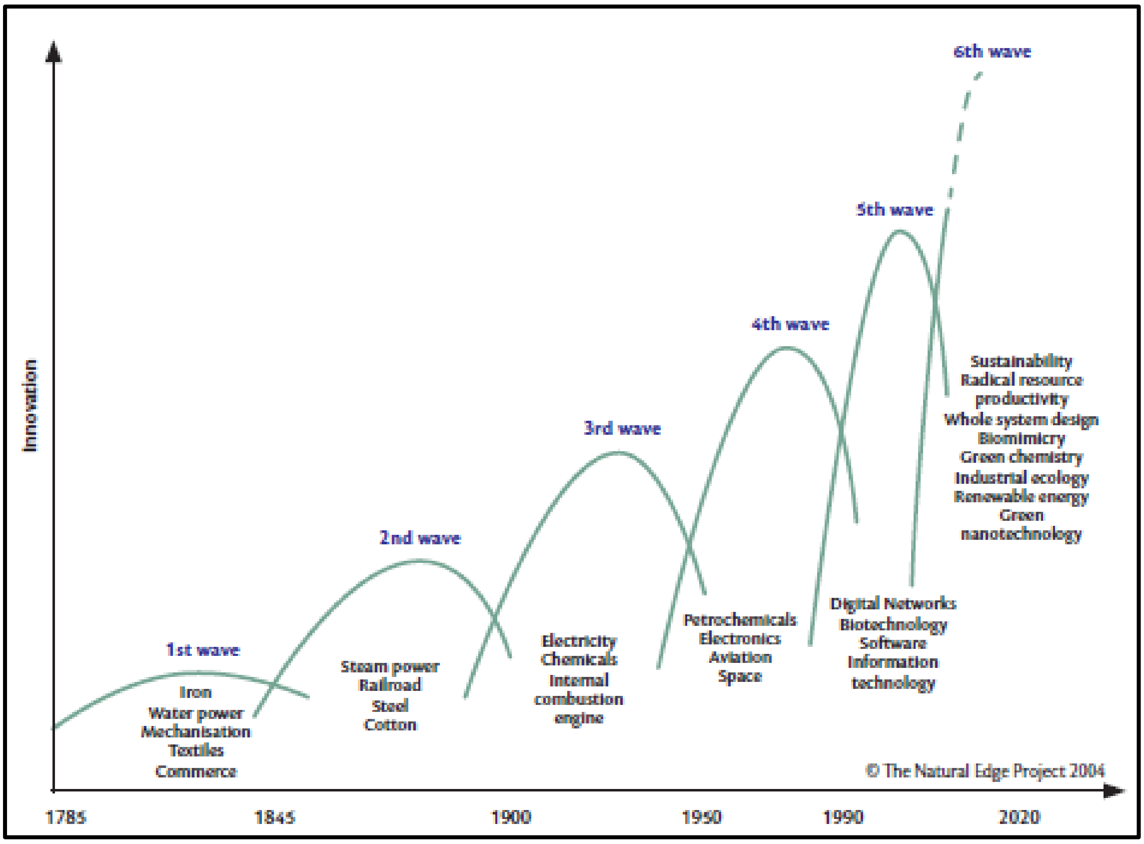


Figure 2:1 Depicts the 'waves' of innovation in engineering and their contributions to human development, from the textile industry to renewable energy

According to *Figure 2:1*, (Marjoram, 2010), the first wave was the Industrial revolution which focused on the textile industry and occurred in the eighteenth century in the United Kingdom, then spreading to Europe and other parts of the world. The second was focused on steam and the railway, the third on heavy engineering based on steel and electricity, the fourth on oil, the automobile industry and mass production, and moving away from the Industrial Revolution the fifth wave was focused on information and technology industry. This was followed by the sixth wave focused on knowledge production and application such as in digital networks, and biotechnology and progressing to, 'sustainable green engineering' protecting the environment as shown in *Figure 2:1*, (Marjoram, 2010: 31). Against this background, engineering education has progressively developed, then further developed to cater for the demands of what is now a global economy.

Engineering education first took place in Germany to accommodate to the mining industry with the creation of a 'school of metallurgy' in 1702 in Freiberg as the foundation for engineering education, and in 1707 the 'Czech Technical University' in Prague was formed as one of the oldest technical universities, (Marjoram, 2010: 31). The French Revolution led to the creation of the 'Ecole Poly-technique' in 1794, where a foundation programme for mathematics and science was first introduced. This system, however, was built on, 'military engineering education', and this model influenced the creation of other engineering polytechnics world-wide in the early 19th century. In the UK, however, engineering training was focused on a, 'system of apprenticeship' and more on practical skills, where practice and experience preceded scientific understanding, and therefore, kept away from formal training and universities, (Marjoram, 2010: 31; Edward, *et al.*, 2014). Engineering conceived as a profession in the UK from the early 19th century until the middle of the 20th century was purely based on engineering practice. In the 1950's, engineering education saw a shift from practice of engineering to engineering science, and this was reflected by fewer faculty members being qualified engineers prior to teaching, (Edward, *et al.*, 2014). Another reform in engineering education came in the 1970's to reduce the gap between engineering science and practice, through to problem solving and engineering project work. Problem solving since then has been one of the defining critical thinking skills of engineering.

2.6.1 Critical Thinking in Engineering

The Subject Benchmark Standard (SBS) for Engineering UK, (2015)*,* which forms part of the*, 'UK Quality Code of for Higher Education'*, and, the Accreditation of Higher Education Programmes (AHEP), (2014), which are rooted in UK Standard for Professional Engineering Competence *(British UK-SPEC)* have outlined the nature of the engineering subject and attributes of engineering graduates.

As mentioned in the SBS, (2015: 6-12), with reference to CTs, the engineering subject '… deals with the practical solutions to problems … addressing some of the greatest challenges and opportunities of our rapidly evolving world' (2.1), 'addresses the complete life cycle of a product, process or service, from conception, through design and manufacture, to decommissioning, recycling, and disposal, within the constraints imposed by economic, legal, social, cultural and environment considerations' (2.2); and 'relies on three core components … scientific principles, mathematics, realisation'. Scientific principles underpin all engineering while mathematics is the language used to communicate parameters, model and optimise solutions. Realisation encapsulates the whole range of creative abilities which distinguish the engineer from the scientist' (2.3). The characteristics of engineering graduates are to take a, 'systematic approach and the logical and practical steps necessary for … complex concepts to become reality', 'be skilled at solving problems by applying their numerical, computational, analytical and technical skills, using appropriate tools', 'be able to formulate and operate within appropriate codes of conduct, when faced with an ethical issue' (3). As for teaching and learning, 'The curriculum includes both design and research-led projects, which develop in graduates both independence of thought … ability to work effectively in a team'.

AHEP, (2014: 12-13) has published six broad areas of learning aligned with the SBS, (2015). The areas which involve critical thinking in engineering are, 'Engineering analysis' and 'Design'. 'Engineering analysis' includes the abilities to, 'monitor, interpret and apply the results of analysis and modelling in order to bring about continuous improvement', 'use the results of engineering analysis to solve engineering problems and to recommend appropriate action, and to 'apply integrated or systems approaches to engineering problems'. 'Design' includes, 'Define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards', 'Work with information that may be incomplete or uncertain', and 'Apply problem-solving skills, technical knowledge and understanding to create or adapt design solutions that are fit for purpose including operation, maintenance, reliability'. It is apparent to meet these requirements engineering graduates must learn and apply CTs for engineering practice, apply problem solving skills, apply systematic and logical steps to identify and resolve problems, and show critical awareness when facing ethical issues. Therefore, it is of paramount importance that the engineering faculty clearly and explicitly state what the accrediting bodies require from graduates and what the faculty expects from them so that they can be active participants in the learning process to develop the relevant skills.

In the context of undergraduate engineering, Ralston and Bays (2015) in their empirical document analysis on engineering conference papers and articles, claim that from 1993 to 2014, about 167 engineering articles and 249 conference papers were mentioned which indicate the growing interest in developing CTs in students. In a survey conducted by Association of American Colleges and Universities, (2011) cited in Ralston and Bays, (2015), 95% of chief academic officers from 433 institutions rated critical thinking as important intellectual skills. Similarly, in another survey conducted by Hart Research Survey, (2013) 93% of 318 employers agreed that the ability to think critically, communicate with precision, solve complex problems are more important in candidates for employment than their undergraduate major. Nevertheless, it remains unclear if students actually develop these skills without empirical research on the development of students' critical skills in their undergraduate studies.

In addition, it is claimed that students at foundation or undergraduate levels may not have acquired complex reasoning and thinking skills, though they may have acquired subject-specific knowledge, (Lewis, Hieb and Whetley, 2010; Arum and Roksa, 2011: 36; Douglas, 2012; Prichard and Mina, 2012). This is because, engineering students at foundation or undergraduate level generally practice idea generation and CTs in controlled laboratories settings at lower level skills, according to Jessop, (2002). Besides that, critical thinking can be quite overwhelming for foundation year students, for they have to bridge the gap between high school experiences and the university environment, which requires self-regulated learning, (Masek and Yamin, 2012). Similarly, this could also be challenging for module instructors as well, for they have to conduct the classes at the right pitch that is not too demanding and threatening.

The issues surrounding the teaching and learning CTs and the key factors affecting their development need further exploration, especially the complexities involving previous learning experiences, academic culture, and academic language. Hence, it is useful to determine if previous learning background, different academic culture and proficiency affect students' acquisition of CTs for instructors planning effective critical thinking instruction.

2.6.2 Faculty's Perception of Critical Thinking

There is a general consensus in the empirical research literature that engineering faculty may have problems in clearly stating the implementation of CTs as an explicit goal in undergraduate engineering. Even where, the skills are well documented, the instructors may have difficulties verbalising what they actually meant, and therefore do not explicitly teach the skills, leading to failure in improving students' critical thinking, (Paul, Elder and Bartell, 1997; Gunnink and Bernhardt, (2002); Mina, Omidvar and Knott, 2003; Papadopoulos, Rahman and Botswick, 2006; Barrie, 2006; de Jager, 2012; Ralston and Bays, 2013: 2015; Amin, Adiansyah, 2018; Jin, Yu-Fang, 2018). There is another claim by Gibbins, Perkin and Sander, (2016), that even where faculty offer undergraduate students a distinct module which explicitly teaches components of CTs, the explicit teaching of the skills often does not continue during their subsequent studies, and this can be reflected in final year students' research-based tasks and final year projects, where many of them fail to demonstrate necessary critical thinking abilities. This supports the view that there is a gap between the faculty's expectation and what students can actually demonstrate in their ability to use CTs.

Barnett, (1997) and Adair and Jaeger, (2015; 2016) assert the importance of clear understanding of critical thinking for misconception can impede the students' development of critical thinking on all fronts. Ahern, *et al.*, (2012) conducted a study to investigate how critical thinking is understood and defined in different disciplines and how CTs are taught in their courses. Semi-structured interviews were conducted with fifteen instructors at an Irish university involving two from engineering, and thirteen from other disciplines. Together with this, documentary analysis was used to look at the module descriptors, course handbooks and students' work to help to produce definitions of critical thinking that could be used for future curriculum reform across disciplines including engineering. The findings from the documentary analysis showed that critical thinking appeared in the module and task descriptors, but without any clear definition of what it was. As for the instructors' perception of critical thinking, there is a significant difference between technical and non-technical instructors' formulation of CTs. The non-technical instructors' conception showed that they had a clearer understanding of critical thinking, which enabled them to conduct discussion to facilitate students to acquire the skills. In contrast, engineering instructors had clear ideas about the importance of critical thinking, but difficulty in verbalising what it actually meant. Ahern *et al*., (2012) argue that it is hard to comprehend how the term can be explained to students and used to motivate them to learn, if engineering instructors are still vague about what critical thinking is, and how it can be identified. Ahern *et al*., (2012) further claim that instructors from the Humanities were well acquainted with critical thinking literature and pedagogical research, and for this reason had clear understanding of the term. This contradicts another interdisciplinary study by Moore, (2013) who investigated ideas of critical thinking as perceived by instructors from three disciplines; humanities; history, philosophy and cultural studies. This study showed, that though critical thinking was acknowledged as one of the fundamental educational goals of higher education, the instructors by and large were not clear about what constitutes critical thinking. Both Moore, (2013) and Ahern, *et al*., (2012) are mostly in agreement with Paul, (2005) and Paul, Elder and Bartell, (1996; 1997), that college faculty at all levels lacks a substantive concept of critical thinking, though they do not realise this, and instead believe they have a good grasp of the skills and are already successfully teaching them.

2.6.3 Teaching Critical Thinking in Engineering

Critical thinking is not a static attribute that can be taught to students as the ultimate destination in their study programme. It is an evolving and dynamic concept that requires expert input, training, and time to guide students to engage actively in learning the skills. One way to promote critical thinking is explicit teaching and demonstration of the skills by faculty instructors. Literature in critical thinking instruction in engineering has made several recommendations to foster the skills in students. One of the most recommended approaches is using a model; (Niewoehner, 2006; Niewoehner and Steidle, 2009) explain that, using conceptual models can be effective, for engineers are quite familiar and comfortable working within this context. The models which have been largely used in engineering context are, 'Critical Thinking Model' of Paul and Elder, (2002), discussed by Niewoehner and Steidler, (2009); Kek and Huijser, (2011); Ralston and Bays, (2013; 2015); Welch, Hieb and Graham, (2015); Adair and Jaeger, (2015: 2016); Michaluk, Martens and High, (2016); Jin, (2018). The 'Instructional Model for Promoting Intellectual Development' (2004) discussed by Felder and Brent, (2004: 280), and the 'Eckensberger's Moral Judgement Model' of Eckensberger, (2003) by Chang and Wang, (2011: 382).

The Critical Thinking Model of Paul and Elder (2002; 1994) has been used as an intervention in experimental research to develop mature engineering thinking in course design, mainly using critical thinking rubrics. Whereas, 'Instructional Model for Intellectual Development, (2004)', (Felder and Brent, 2004)', was incorporated in teaching to provide support to advanced engineering and science students to promote their intellectual development to the level of scientists and engineers. The 'Eckensberger's Moral Judgement Model,' (2003), has been used for systematic cultivation of engineering ethics using real case study, i.e. an investigation of the China earthquake of 2008, which killed over 80, 000 people mainly due to structural deformity of houses and schools, (Chang and Wang, 2011).

Paul and Elder's Critical Thinking Model, (2009; 2002), was adopted by Adair and Jaeger, (2015: 2016) to investigate how students can be exposed to CTs, and how the skills can be developed through practical experience through an 'Introduction to Fluid Mechanics' (an engineering module) to develop principles of logic and obligatory problem solving procedures. The model was incorporated in the course to train students to become mature engineering thinkers. The course lasted one semester in the engineering preparatory year (Level 0) of an engineering undergraduate degree, and was implemented through lectures (demonstrations) explaining the model, group discussions, and individual practice and analysis of a sample of engineering designs as introduction to, 'elements of thinking' the second component of the Paul and Elder' model which focused on sound reasoning and evaluation of how people think. The research showed that the faculty concerned were enthusiastic about the incorporation of critical thinking using the model as an integral part of the selected course, but were not in agreement about testing critical thinking as a separate component of the designed course, because the teaching and learning course content would be affected. In addition, the faculty objected to the lack of standardisation of marking between assessors. However, the overall findings showed a significant improvement among students in learning when the CTs component were included.

The Paul and Elder model was also adopted in engineering education by Niewoehner and Steidle, (2009), and Welch, Hieb and Graham, (2015) as a template to critically analyse case studies of failure. Niewoehner and Steidle, (2009), evaluated the suitability of Paul and Elder's model to analyse documents produced by the Columbia Accident Investigation Board (CAIB), which detailed a report (chapter 6) of multiple meetings within and between programme teams on their decisions regarding the condition of the space shuttle Columbia during the final take off and the consequences for its return flight. The critical analysis and discussion of this case study mainly focused on the dysfunction of a particular team during small meetings and personal communications, without involving the dysfunction of the entire National Aeronautics and Space Administration (NASA) team. The model comprises three main components 'Essential Intellectual

Standards' checks quality of reasoning, 'Elements of Thought', evaluate how one and others think and, 'Intellectual Traits', cultivate personal intellectual values to think with insight and integrity. Together, these provide a starting point for the students to systematically and logically analyse the incident with guidance from the instructor. According to Niewoehner and Steidle, (2009) this critical thinking process is not just restricted to logic, but includes metacognition, which is 'thinking about the thinking'. For example, NASA claimed, 'nothing could be done about such an emergency'. This could allow students to analyse the quality of NASA reasoning, whether it was influenced by biases, bureaucracy or organisational culture which failed to reflect and monitor the thinking of individual engineers and that of others. This case study involved reflection on the bright and hardworking team who raised concerns about the safety of the mission, and why these concerns were dismissed by the leadership as a minor issue, which led to one of the worst aviation disasters.

Welch, Hieb and Graham, (2015), on the other hand, also use Paul and Elder's model in their case to apply a systematic approach to include broader critical thinking instruction into electrical and computer engineering education as a part of Electrical and Computer Engineering (ECE) programme involving real world projects. The study involved all incoming freshmen in University of Louisville (US), and the students were given explicit and implicit instruction in the piloted introductory engineering programme. 100 students from the programme were given explicit instruction on Paul and Elder's model during a lecture, where, 'Elements of Thought' and, 'Essential Intellectual Standards' were explained and demonstrated. After the lecture, students in groups of thirty were asked to discuss which, 'Elements of Thought' were important for problem solving. Then, students worked individually on four to five problems that require critical thinking, for example, word problems, the NASA moon survival problem, and later a failure case study in engineering, 'Hyatt Regency Walkway Collapse', in Kansas City in 1981 which killed 114 people. Students finally wrote a reflective report. The pilot implementation of the model in ECE showed statistically significant improvement in CTs. There was an indication that students' writing skills also improved through this process. Michaluk, Martens and High, (2016), in their research on teaching and evaluating CTs also attempted to improve 49 foundation year students' CTs through two assignments based on Paul and Elder's model. This study had similar findings claiming that development in critical thinking contributed to improved writing skills as they involve the same process.

It has been claimed that explicit teaching of problem-solving skills can also contribute to high level critical thinking dispositions. However, while there are several published papers on engineering and problem solving, (Lunt and Helps, 2001; Dym, *et al*., 2005), they are mainly discussions on the importance of problem-solving skills. Ozyurt, (2015), provides an empirical research study to examine the relationship between critical thinking dispositions and problem-solving skills. The study involved 186 computer engineering students in a university in Turkey at the beginning of 2013-2014 academic year. The data was collected using the California Critical Thinking Dispositions Inventory (CCTDI) and the Problem Solving Inventory (PSI). The findings indicated that the students had high level critical thinking dispositions and problem-solving skills. However, no statistically significant relationship was found in the problem-solving skills levels of the students by gender and grade. This study emphasised that engineering students, particularly computer engineering students already have high critical thinking dispositions, therefore, they are highly skilled problem solvers. This study supports Pawley's (2009) claim that computer engineering students generally have high level problem solving skills, due to the close relationship between engineering practice and problem solving. In addition, Jonassen, Strobel and Lee, (2006) and Huntzinger, (2007) claim that engineering requires problem solving skills, therefore engineers must possess high problem solving skills as professionals.

2.7 Conceptions of Critical Thinking: a Brief History

The idea of liberal education where CTs play a key role has connected history, which largely belongs to the intellectual life of Europe, especially identified with Socrates the Greek philosopher. Socrates encouraged his students to challenge the received knowledge and wisdom through the Socratic Method, *dialogue and questioning*, (Dewey, 1938; Siegel, 1988; Moore, 2011: 7-9). However, similar intellectual traditions are also claimed to have been widespread in other parts of the world, according to Axelrod, (2002: 9-10), in ancient Egypt, Mesopotamia, India and ancient China. Richmond, (2007), argues that China and India organically have their own logical and argumentative thinking tradition for more than two thousand years, and Indian tradition of logical thinking is claimed to be home grown and not influenced by *Aristotelian* ideas.

Later, the post-Roman period has seen a disruption in intellectual activity
in Greece and much of Europe. According to Halstead, (2004: 517) intellectual traditions started to spread and flourish elsewhere, such as in the Middle East. Hence, it can be argued that, traditions of rational inquiry and critical thought do not solely belong to a European tradition, (Halstead, 2004; Richmond, 2007; Johnston, *et al*., 2011). Johnston, *et al.*, (2011) further point out the idea of promoting liberal education, and critical inquiry in the medieval period in the European university was only for the highly intellectual and privileged, particularly to groom civil administrators, train lawyers, medical personnel, and create scientists, but not scholars in arts or philosophy. Only a tiny fraction of the population had the opportunity to be immersed in critical and scientific inquiry during the post-Roman period.

The early nineteenth century, saw a conflict between the aspired secular liberal education, which continued in Europe and North America, and a continuing religious movement, for example Anglican (religion) controlled universities in England, Oxford University and Cambridge University, (Fuchs, 2004; Riley, 2004; Johnston, *et al.*, 2011). The religious based inquiry model of the universities was built on two strong pillars, one was critical theory and the, *enlightenment*. Brookfield, (2003) pointed out this in a sense is religiously-bound. Thinking is guided by a set of moral values prescribed by a particular elite religious community. Therefore, it is a culturally situated critical thinking model, which deviated slightly from the original scientific inquiry, according to Brookfield, (2003).

In the beginning of the twentieth century, came a new era, a contemporary education which is grounded in hybrid practice, including an exchange of intellectual tradition among philosophers from different parts of the world, (Saito and Imai, 2004; Shenhong and Dan, 2004). Among them, Dewey, the American philosopher, became a prominent figure in a radical and progressive education movement, who promoted the concept of, *reflective thinking*, (Siegel, 1988; Lipman, (2003); Moore, 2011: 7-9), which is aligned with the earlier intellectual tradition; rational inquiry and critical thought.

Dewey, (1910: 6), defines the idea of, *reflective thinking*, as

> Active persistent and careful consideration of a belief or supposed form of knowledge in the light of the grounds which support it and the further conclusions to which it tends.

This can be further defined as thinking being an active process, which needs determination to recognise the emerging issue and find solutions based on evidence, and take responsibility for the consequences of the decision made. According to Dewey, (1910: 10-12), *reflective thinking*, is a conscious inquiry to seek the truth involving reflective operations. The action is deliberate and, purposeful, the basis for a belief is persistently sought and the adequacy of the ground of belief which stands as evidence, witness, proof, voucher or warrant to support the belief is scrutinised and revised. However, this inquiry is restricted by excluding grounds of belief that are not directly perceived by human senses; see, hear, smell or taste. Dewey, (1910), further emphasised that, apart from the persistent inquiry to scrutinise and revise the grounds of belief, the purpose of the thinking itself should not be influenced by any traditions, instructions, imitations, depend upon authorities, appeal to one's advantage, and pre-judgements, but rely upon survey or evidence to avoid thinking which lacks value. Therefore*, reflective thinking* helps one to be responsible and ethical, so as to produce a valid conclusion or decision to corroborate or to nullify the suggested belief or argument based on evidence.

Dewey's idea of *reflective thinking* has been developed and evolved into *critical thinking*, and has been simplified by various philosophers according to time and needs for example Glaser, (1941), Ennis, (1989), and Fisher, (2001). This evolution and the attempt to conceptualise critical thinking, however, has also led to conflict among critical thinking scholars with some defending a philosophical approach which relies mostly on logic and sound reasoning as the end product of thinking, and others focusing on the process of achieving desired outcome as critical thinking. Others, champion dispositions and attitudes as critical thinking in which without these there is no motivation to engage in critical inquiry. Therefore, before trying to conceptualise what critical thinking is for the purpose of this thesis, it is useful to look at some of the consensus and conflict among critical thinking scholars to have a better understanding of the still on-going debate on the conceptualising critical thinking in higher education particularly.

2.7.1 Defining Critical Thinking: Consensus and Conflict

The concept of critical thinking has evolved in definition since the Socrates theory of *dialogue and questioning* which entails rational inquiry and critical thought, (Lipman, (2003); Johnston, *et al*., 2011; Moore, 2011). Different philosophers have developed theories of critical thinking based on their philosophical stance, for example, modernist theorists conceive the term as ability and dispositions, (Ennis, 1989; Halpern, 1999; Siegel, 1999; Kwak, 2007) as a technique, a process of thinking and as a product, (Lipman, 2003; Moore, 2011). On the other hand, Brookfield, (1987) and Paul (2005) focused on the performance of the critical thinker.

Despite the fact that there is a conflict among critical thinking scholars in conceptualising critical thinking, their positions however endorse strongly the importance of, *reason,* and a commitment in recognising the principles and skills of critical reasoning as the most fundamental attributes that a critical thinker must possess. Martin, (1992), however, argues that emphasis should be given to the attitudes or dispositions associated with critical thinking which is grounded in moral perspectives and particular values, rather than just to reason. In this context, the purpose of critical thinking should be guided or motivated by a care for a more humane and fair world. Martin, (1992) defends that, just because a *critical thinker* may have achieved a solution by applying some brilliant critical reasoning, this does not always justify his or her solution or conclusion as morally acceptable. This rejects Siegel's, (1990; 2002), epistemological anchor for critical thinking which stresses a strong connection between critical thinking and rationality in which 'reason' takes the centre stage, and to be rational one needs to believe and act on the basis of reasons and anything other is feared to move down into relativism, (Mason, 2007). As for Phelan, (2001), critical thinking which depends solely on reason is reduced in its ability to respond to real and practical issues which could not be confined by reason, for example, abused children, domestic abuse, sex victims, war refugees and others.

In addition to this, there is disagreement among the critical thinking movement theorists and scholars in defining what CTs are, whether they are process or product, (Lipman, 2003; Moore, 2011). Whilst there is still an on-going debate about conceptualising CTs as discussed however, the descriptors used to define the skills, for example, *purposeful, reasoned*, and *goal-directed thinking*, appear to be consistent in the literature across disciplines, according to Halx and Reybold, (2005: 294); Scriven and Paul, (2007) and Moore, (2011). Furthermore, the weight of evidence is found to be crucial in almost all disciplines in producing a logical solution to a problem or a valid conclusion to an argument, claim Brookfield, (1987); Halpern, (1999); Lipman, (2003) and Dwyer, Hogan and Stewart, (2012).

Apart from the issues discussed above, critical thinking has become more difficult to define in recent years due to assimilation of knowledge, culture, and emerging new academic disciplines and schools of thought. Thus, the definitions of CTs vary across disciplines, for example, in the field of education, (Swales and Feak, 1994). According to them, different disciplines observe different stances, for example, Science and Engineering employ CTs in application of a result in problem solving, whereas, Humanities focus on constructing arguments. On the other hand, Social Sciences apply CTs differently, whereby the skills are used more in determining methodologies to respond to phenomena under investigation. (See Section 2.5 above for our own review of disciplinary differences in education in critical thinking.)

Critical Pedagogy, is another interpretation of critical skills developed by Freire, (1970) a Brazilian educational activist who advocates teaching and learning practice based on teachers taking a major role in instilling critical skills, (cited in Benesch, 2001). This pedagogy is largely focused on questioning, an authentic dialogue between teachers and students. Teachers who employ critical pedagogy use their class as platforms for students to critique the interlocking systems of oppression embedded in the society, (Benesch, 2001; Brookfield, 2003) for example, caused by political stance, socio-economic inequality, fanaticism, culture, religious, beliefs and others.

Although the theorists and scholars of critical thinking are not in consensus about some aspects of CTs, they agree that critical thinking is purposeful thinking to produce a valid conclusion based on sound reasoning supported by reliable evidence. This, however, is not substantive enough to understand the conception of critical thinking in education and the practices that affect students' ability to learn and develop the skills in their university education. University educational practices are largely influenced by educator's pedagogical choices which have direct impact on students learning and developing their intellectual traits. Barnett, (1997) asserts that the uncertainties surrounding the pedagogical issue of conceptualising critical thinking explicates the inadequate thinking about the issue. Hence, it is important to find how the term is conceptualised in both a general philosophical approach and subject-specific context before the research investigates how academics or educators conceptualise critical thinking.

2.7.2 Conception of Critical Thinking: a Philosophical Approach

The philosophical approach to conceptualise critical thinking is mostly grounded in informal logic and sound reasoning, (Kurfiss, 1988; Johnston *et al.*, 2011). This approach is usually used in Humanities disciplines, such as philosophy, literature, language, film, history and others which give importance to sound reasoning to engage in critical analysis for intellectual arguments.

Glaser, (1941: 5-6), includes, a*ttitude* and, *disposition*, in defining critical thinking concepts. He outlines three components of critical thinking, (i) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, (ii) knowledge of the methods of logical inquiry and reasoning, and (iii) some skills in applying those methods. That is, in order to seek the truth, one needs to have the attitude, knowledge of the subject matter, and certain thinking skills at one's disposal, and be able to use them to find a valid conclusion in a certain methodical manner. In other words, critical thinking is not about just knowing the theory, but the ability to apply the skills appropriately in a real context in a skilful and logical way in an attempt to bring to light further facts to enable one to accept or reject a conclusion or decision.

Apart from Glaser, some of the other most influential philosophical conceptions of critical thinking are found in Ennis, (1962; 1987; 1989); McPeck, (1981); Siegel, (1988); Lipman (1988; 2003); Paul, (1985; 1989). Ennis, (1989) defines critical thinking as, *a reasonable reflective thinking that is focused on deciding what to do or believe*. This can be conceived as a reasonable and purposeful act in finding a solution as such, i.e. critical thinking is seen as an act of seeking the truth to produce a valid decision. On the other hand, Fisher, (2001: 13), interprets critical thinking as, *critico-creative thinking*. Here, Fisher explains, critical thinking is about evaluative thinking which involves both *criticism and creative*, thinking. The criticism could be either positive or negative, however the quality of reasoning is important to defend or to refute a claim, which largely focused on learning from creative disaster.

Another critical thinking theorist, Lipman, (2003: 26) conceptualises *reflective thinking*, as an overlap between methodological thinking and substantive thinking. For example, thinking about logic or a mathematical solution is procedural or methodological thinking, while thinking focused on content is substantive thinking. Reflective thinking according to Lipman (2003) involves thinking about procedures and subject matter at the same time. For instance, a deliberative inquiry session in a classroom must be monitored so that attention is given to the methodology of such inquiry while the subject matter is discussed to avoid bias, prejudice and self-deception which could affect the quality of the decision made.

Conceptualising critical thinking using a philosophical approach was also adopted in the 'Delphi Report', (Facione, 1990), an interactive panel of 46 experts in critical thinking theory, critical thinking assessments, and educators including Ennis, Facione, Lipman, Norris and Paul. This was initiated by the American Philosophical Association in response to the major success in critical thinking development in the eighties in schools and universities, through standardised testing programmes, dissemination of critical thinking papers in conferences, publications of books and critical thinking staff development programmes. In response to the success also came raised expectations from stakeholders and investors for educators to teach and assess students to develop their cognitive skills and affective dispositions for students to become good critical thinkers. The Delphi team was given the responsibility to make a systematic inquiry into defining the concept with clarity for pedagogical and assessment use.

Using the philosophical approach, a consensus statement of critical thinking was produced in the Delphi Report (Facione, 1990: 6) as follows:

> *We understand critical thinking to be purposeful, self-regulatory judgement which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgement is based. CT is essential as a tool of inquiry … CT is a liberating force in education and a powerful resource in one's personal and civic life … CT is pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgements, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in selection of criteria, focused in inquiry, and persistent in seeking results which are precise as the subject and the circumstances of inquiry permit. Thus, educating good thinkers means working toward this ideal*

The key words in critical thinking found in the Delphi Report, *purposeful, self-regulatory, conceptual, methodological, criteriological, contextual, tool of inquiry, self-rectifying*, describe the process of critical thinking involved in a systematic inquiry of a problem or issue which is goal oriented and needs independent involvement, based on particular concepts and criteria which are, logical, context-bound and self-correcting. The skills are a tool or a thinking instrument applicable in most inquiries to achieve a valued and desired outcome. Whereas, the key words: *habitually inquisitive, well-informed, open-minded, fair-minded honest in facing personal bias, diligent in seeking relevant information, persistent in seeking results* capture the intellectual traits which a good thinker needs to engage in a critical inquiry. Philosophers like Paul and Lipman who participated in the Delphi Report later designed various critical thinking models, like *Paul's Critical thinking Model for Critical Reasoning,* (Paul, Niewoehner and Elder, 2006), which we discuss more fully in Chapter 3. Similarly, Lipman, (2003: 282) produced *The Wheel of Judgment*, as guides for students to develop their CTs.

Philosophical approaches in defining critical thinking have both their own distinctive characteristics, and certain limitations. Most of the distinctive characteristics have been discussed above, and we next discuss the limitations of their applicability in an engineering context. Firstly, the reasoning is mostly theoretical without empirical ground. The goal of critical thinking in a philosophical approach is not to find and execute scientific solutions to problems, but to use a methodological approach to construct sound reasoning to represent the issue or the situation under inquiry in a convincing argument in a wider context, which usually ends when a conclusion is agreed. On the other hand, in engineering inquiries, students are encouraged to use different scientific methods to solve an engineering problem, and must generate one or more hypotheses to achieve an engineering solution, (Johnson, 1992; Huntzinger, 2007; Lewis, Hieb and Wheatley, 2010; Douglas, 2012). In engineering the inquiry also continues after a solution is established to test their hypotheses until the goal is achieved, (Kurfiss, 1980). Therefore, to use a philosophical approach alone to define critical thinking for engineering use would not be adequate.

Philosophical conceptual frameworks and thinking models are largely built on philosophical speculations and assumed views. Johnston *et al.*, (2011) point out that when used in education, such frameworks are generally based on what educators want the students to acquire, and is not informed by empirical research data of what students actually need to improve their skills. Moreover, the existing critical thinking frameworks were mostly influenced by western philosophical ideology and western education systems, so that students from non-western education could find them challenging to learn and apply in their critical inquiry. Therefore, taking into account students' cultural and academic background, their disciplines' requirements and other relevant information collected through empirical research could produce a more informed and meaningful conception of critical thinking to design critical thinking framework or models for pedagogical use and students' development in the skills. Thus, critical thinking conception built on both informal logics and scientific empirical method will be more useful for purpose of this study, which is to investigate the development of engineering students in their foundation year.

2.7.3 Conception of Critical Thinking in Subject-specific Fields

There is an on-going debate whether academic CTs are transferable and are best taught as generic or subject specific skills, (Ennis, 1989; McPeck, 1990; Siegel, 1992; Atkinson, 1997; Smith, 2002). McPeck, (1981), unlike Ennis, (1989) argue that critical thinking is context-bound, therefore, knowledge of the discipline is important in order to think critically in the discipline, for example for an electrical engineer to solve a problem involving circuits it is important to be competent in the discipline before applying the relevant skills to come up with a solution. McPeck, (1990) argues that, thinking should be taught through disciplines rather than as in generic skills contradicting with Ennis, (1989) who claims critical thinking as generic skills are applicable to all disciplines. Similarly, in a recent empirical research, Johnston *et al.*, (2011) who investigated the development of student criticality in higher education within undergraduate learning in Arts and Social Sciences, further emphasise that context plays a crucial role in the exercise of criticality.

Dewey's view on field-specific contextualism (1938) cited in Pasch (1959: 818-822), suggested the importance of context for thinking to take place …

> The trouble is not with analysis, but with the philosopher who ignores the <u>context</u> in which and for the sake of which the analysis occurs … There are a multitude of ways of committing the analytic fallacy. It is found whenever the distinctions or elements that are discriminated are treated as if they were final and self-sufficient. The result is invariably some desiccation and atomiz-ing of the world in which we live or of ourselves

Dewey describes the importance of context for any philosophical thinking and ignoring it could be going against the purpose for truth-seeking to resolve a problem or issue. Context provides space for multiple thinking which could not be reduced to a single absolute solution in a multifaceted world.

Such an approach, which seeks to teach CTs in context-bound setting is very important in engineering education. For example, in civil engineering, design-related projects in sustainable development involve environmental management which largely comes with engineering uncertainties. For example, for a civil engineer to design a highway there needs to be focused on the context, i.e. structure of the land, rather than, the structure itself, making specific technical and environmental decisions based on soil conditions, materials, and construction technologies, (Siller, 2001: 105). From this perspective, teaching students to think critically through situated learning is required to increase high level critical thinking among the students. In Section 2.5

above, we reviewed briefly some examples of disciplinary approaches to critical thinking education in such context-bound or situated setting.

2.8 Dewey's Reflective Thinking and Engineering Study

This research adopts Dewey's *reflective thinking* as a foundational conceptualisation of critical thinking, which has been developed and evolved into CTs, and adapted by the members of the critical thinking community according to time and needs. Dewey's, (1910) *reflective thinking* stressed the importance of process and product in thinking. *Reflection* encourages the learner to pause and engage in deep thinking when faced with a problem or issue before attempting to solve the problems.

> … <u>active, persistent</u>, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the <u>fuller conclusions</u> to which it tends … (Dewey, 1910; 1938)

Reflective thinking goes through a methodological process to seek the truth based on evidence to achieve a valued outcome which is the product of the thinking process. The process of thinking and the product, which is the conclusion or solution have equal weight in *reflective* thinking, which is relevant for scientific thinking in engineering study. Rodgers, (2002: 850-856) outlines six phases of reflection in scientific method expressed in Dewey (1910; 1938):

i. An experience

The purpose of thinking is triggered when by encounter with a situation or a problem which comes with a significant need for a solution. The experience opens up to an unknown or incomplete understanding of the situation which could be due to inadequate knowledge of the subject matter. This experience could lead to a haphazard action to solve the problem which could result in unintended outcomes. In an engineering context this could lead to a technical disaster which could be fatal to public, affect environment and cost. Therefore, reflective thinking could avoid haphazard action to solve a problem;

ii. Spontaneous interpretation of the experience

Dewey's *reflective* thinking identifies the need to slow down the interval between the thought and action. *Reflection* gives the space and willingness to endure the suspense and determine to search for a solution based on evidence, and scientifically to seek the truth. In engineering context this can be achieved through observation of scientific experiment;

iii. Formulating the problem

In *reflective* thinking formulating the problem is essential as Dewey identifies this stage as intellectualisation in which the experience allows the distancing of the problem, so that one could see it *like a piece of art work*. This *reflective* process helps in formulating the problem to answer. According to Dewey, *a question well formulated is half answered*, as meaning making or conceptualisation of the problem has begun. For example, in questioning the intellectual integrity of an engineer, he could question to what extent my contradictions do and inconsistencies affect the way I deal with technical issues? *Reflective* thinking allows the limitations or the weaknesses to be identified before a potential technical error is made;

iv. Generating possible explanations for the problem(s) or questions(s)

Generating hypotheses is the first phase of analysis of the problem in *reflective thinking*. This adds to the already initiated process to hunt for the truth in which a now more complex approach takes place where the process of synthesis begins. This process brings together the available resources, literature, expertise consultation, more empirical or scientific observations to conceptualise the problem. In engineering problems this could be a model building stage to test its durability before it could be up scaled for a further test;

v. Ramifying the explanation into full-blown hypotheses

This phase of thinking revisits the analysed evidence or data used to generate the explanation for the problem for its depth and breadth to see if there are any complexities or difficulties that need to be dealt with. Or, if there is a need to look at it from different perspectives or points of views with good reasoning and understanding from which intelligent action can be taken. This is crucial in an engineering context as engineering invention needs to go through various stages of quality control and endorsement by various engineering bodies, engineering higher learning institutions, stake-holders, private investors, environmental activists, public representatives and others. Therefore, *reflection* and revisiting the generated explanation of the problem is important to avoid any disapproval or rejection of the proposed solution;

vi. Experimenting or testing the selected hypotheses

A *reflection* on a problem needs to be followed by an action and if it does not lead to action then it does not fulfil the criteria of reflective thinking because it falls short of being responsible, that is, thinking about a problem without taking the responsibility to investigate and resolve the problem is not reflective thinking. Therefore, at this stage of reflective thinking the experience or the experiment needs to be tested for its reliability and validity to offer a possible solution to the problem or bring a closure to the inquiry. Bringing a closure to inquiry is important in scientific experiment in engineering to test the recommended theoretical or empirical evidence for its suitability for a technical invention.

This research is focused on investigating critical thinking development in an engineering context, and has adopted Dewey's reflective thinking (1910; 1938) to conceptualise critical thinking for its suitability for foundation engineering study. The research conceptualises critical thinking as…

> An active process of reflective experiment, persistent, and careful consideration of any beliefs or supposed form of knowledge and technical concepts in the lights of the grounds that support it and the fuller conclusions to which it tends.

This definition which is built on Dewey's *reflective thinking* give distinction to *reflection*, experiment, knowledge in the subject matter and technical concepts, so as to seek the truth in engineering inquiry, and to produce a valid, valued and comprehensive solution.

The present study, chose to adopt Dewey's definition as a main starting point to explore the phenomenon under investigation, however, the importance of defining what CTs are for engineering should not be side-lined.

2.9 Developing Critical Thinking and Critical Being

Critical thinking is an active process which does not function in isolation but through interactions among the skills. Critical thinking which includes series of feedback and interactions among the skills allow a thinker to self-reflect to think about his or her own thinking and develop his or her critical being.

Paul, (1982), further developed our understanding of what it means to be critical thinker or critical being, when distinguished between weak and strong interpretations of critical thinking. Here, the weak sense implies the ability to appreciate the views or positions of others, and to make value judgements, whereas, the strong sense refers to the ability to analyse critically and reflect on one's own position. As a consequence of this, a strong critical thinker will have the capacity to understand the different views holistically and appreciate the difference and learn the concept of tolerance. Paul, (1985: 4), further asserts that critical thinking is about analysing the mode of thinking, *in which the thinker improves the quality of his or her thinking by skilfully taking charge of the structure of thinking and imposing intellectual standards upon them.* For Paul and Elder, (2014a) in teaching and learning environment, students can be perceived as the thinkers and teachers as providers of opportunities to help students improve and develop their thinking by exposing them to a *Model for Logical and Rational Mind*, shown in *Figure 2.2 (on p 34).*

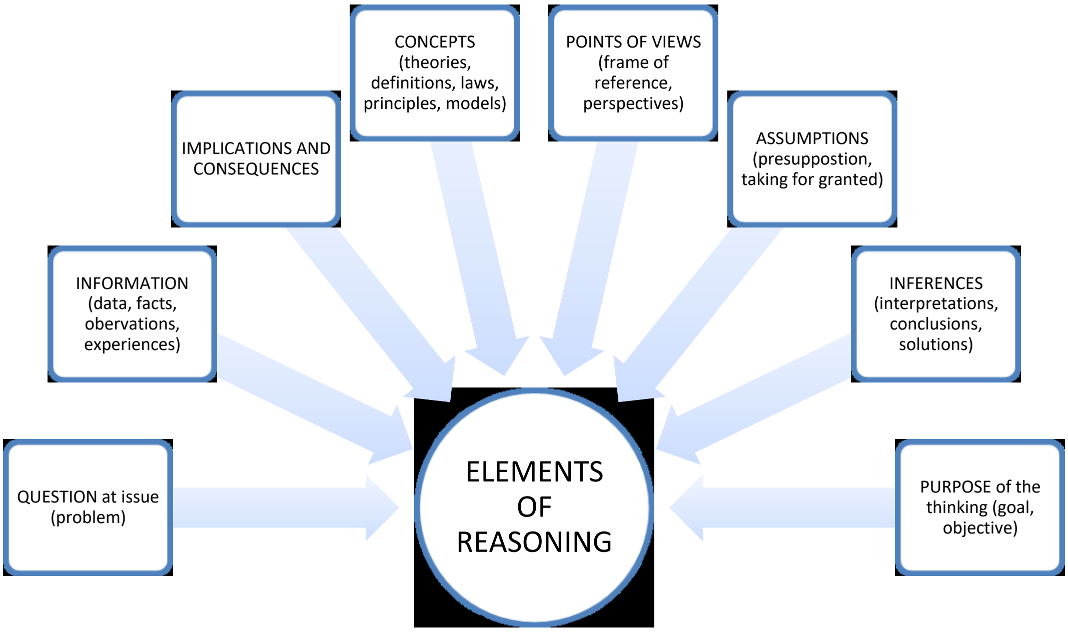


Figure 2:2 Model for Logical and Rational Mind (adapted from Paul and Elder, 2014a)

Paul and Elder, (2014a) believe that training the mind in sound reasoning could help in developing a rational mind. Based on their model, a critical thinker needs to develop oneself as a rational thinker intrinsically, before embarking on tasks which demand a high level of thinking skills to solve a problem or for decision making. The purpose of any thinking needs to be identified first, and any thoughts that are skewed towards self-interest need to be avoided. Identifying the key problems is important for desired outcome. Reasoning needs to be supported with valid data or facts, and currency of the data is equally important. Any assumptions based on self-belief and not supported with evidence need to be removed. Inferring reasons should be based on objective interpretation, for reliability testing. Reasoning needs to be based on different views and perspectives, and not skewed towards a single uncontested perspective. In order to achieve a valued decision the elements of reasoning need to be methodically based in any models or principles in the issue which is being discussed or investigated.

In alignment with Fisher and Scriven, (1997: 21); Paul and Elder, (2014a) also appear to focus on the process of thinking and the thinker: 'Critical thinking is skilled and active interpretation and evaluation of observations and communications, information and argumentation'. In other words, critical thinking needs to be a skilful and rigorous activity, for it demands interpretation and evaluation of what has been observed, and communicated, which could be information or facts which are linear, non-linear, or abstract. Critical thinking here is about the approach or mode of thinking the thinker takes, for it determines the quality of the decision or conclusion made. To develop in this way requires practice and expert input, which could be effectively through modelling in the teaching and learning context.

Hence, in both general and academic contexts, the idea of critical thinking rejects the notion of rote learning, and memorisation of facts, but promotes experiential learning through *critical reflection*, and rigorous thinking based on certain standards to understand the process involved, so as to achieve reliable claims or valid conclusions, (Paul, 1985; Fisher and Scriven, 1997; Gellin, 2003). Thus, this concept of critical thinking is vital for contemporary education where students in the higher learning institution are flooded with information readily available in a massive open access environment

Paul, (1985), asserts that, *good thinking* is vital in the discovery and acquisition of knowledge. For example, students with good understanding of the criteria for good thinking in selecting learning materials will have the ability to distinguish between what is relevant and irrelevant, interpret the content, analyse its merits and limitations, and make decisions for selection of materials based on relevance for their area of study. Thus, it is important to identify what CTs entail, which of the skills are relevant to students at various levels of their study, and how they could be developed through appropriate pedagogic strategies. Nevertheless, conceptualising, recognising and implementing the skills in EFY and English for Specific Academic Purposes (ESAP) course could be a challenging endeavour made more complex today by factors such as variability in target language, previous learning experience and culture.

2.10 Conclusion

The investigation of the issues surrounding the research focus which are CTs and the engineering foundation year students' development of critical thinking needs a theoretical framework to conceptualise the research in a broader context for a better understanding of the knowledge in critical thinking. Therefore, the next chapter will provide a detailed recount of the conception and design of the research conceptual framework for critical thinking before discussing the research method.

Chapter 3 Conceptual Framework for Critical Thinking for Engineering Foundation Year

3.1 Introduction

The purpose of this PhD research is to find out how students in the Engineering Foundation Year develop their critical thinking skills (CTs), and in what way this is supported by educational practices. The research is an exploratory project focused on Engineering Foundation Year (EFY) students' critical thinking development therefore, it was important to select a conceptual framework, which could help in producing meaningful findings to respond to the research questions.

The foundation engineering education is a unique programme, for its diversity of students from different academic qualifications, i.e., international and European students from non-British education and without A-Levels. Foundation Year (FY) for British students includes those without the traditional entry qualifications of A-Levels in core engineering subjects, maths and physics. Besides that, they are also diverse in types of previous schooling and academic culture and language. Therefore, the study needed a conceptual framework, which could accommodate to the differences and similarities in identifying how students learn and develop CTs. A single framework would have excluded useful data, which could illuminate the actual issues surrounding the foundation engineering programme. Hence, the research has adopted a blended framework made up of three types of critical thinking models to maximise the inclusion of types of source data from different perspectives to avoid any bias in the types of source data collected, and in analysing the findings.

The first critical model identified as relevant to the research is Dewey's widely used model of scientific thinking, (Dewey, 1910). However, Dewey's model only outlines the process of thinking without attention to the learner as the thinker. Hence, another critical thinking model, The Paul, Niewoehner and Elder Engineering Reasoning Model, (2006) was identified to complement Dewey's approach. This model focuses on the learner and provides a discipline specific perspective, as it explains in detail the intellectual standards and intellectual traits essential for engineers.

Although both Dewey's and Paul, Niewoehner and Elder's models are established models for critical thinking, they have some limitations because they were built on theoretical grounds without ratification by any professional body to validate their suitability for engineering undergraduate studies. Therefore, the research turned to another framework, or model as a third source. This is the v2.0 Syllabus of the Conceive Design Implement and Operate (CDIO) Thinking Model, (Crawley, *et al*., 2011).

All the three selected models were then combined as a blended conceptual framework to guide the PhD research, to design the study and interpret the research findings. The details of each model will be discussed in the following sections.

3.2 Dewey's Logical Considerations (1910)

Dewey's concept of reflective thinking and its relevance for engineering studies has been discussed in the previous literature chapter (Chapter 2.8 on p. 31). This section explains the rationale for adopting Dewey's Logical Considerations (DLC), (1910) to design the study conceptual framework.

Dewey's Logical Considerations (DLC) are proposed in his 1910 book *How We Think*, (1910: 68-145). They explain his conception of critical and reflective thought, which emphasises experiential learning through reasoning and experiment. Dewey's reflective thought starts with an attempt to define the situated problem and to formulate by identifying any incomplete information. This then triggers the need for the acquisition of knowledge and further research into the conditions of the situation or the problem (Dewey, 1910; 1938; Miettinen, 2000). Dewey says the desired outcome of these thought processes can only be achieved by practical testing of hypotheses in material activity through scientific inquiry, so as to draw conclusions about their validity (Dewey, 1910; 1933). The centrality of problem definition and problem solving in Dewey's reflective thought aligns with the fundamental way of engineering thinking which focuses on problems and bringing them to a closure or solution, (Siller, 2001; Niewoehner, 2006; Douglas, 2009). Hence, Dewey's, Logical Considerations, was selected and adapted for its relevance to the context of the study, which is concerned with critical thinking development within foundation engineering programme.

Dewey's Logical Considerations (Dewey, 1910: 68-156), comprises five processes of reflective thinking: (i) Analysis of a Complete Act of Thought (ACAT); (ii) Systematic Inference: Induction and Deduction, (SIID); (iii) Judgement: Interpretation of Facts, (JIF); (iv) Meaning: Conceptions and Understanding, (MCU), and (v) Thought: Abstract, Concrete, Empirical and Scientific (TACES). All five steps or processes of thinking are mutually related.

3.2.1 The Analysis of a Complete Act of Thought (ACAT)

The *Analysis of a Complete Act of Thought* (ACAT) focuses on the analysis of thinking into elementary constituents basing the analysis upon descriptions of reflective experience: (i) practical deliberation, (ii) reflection upon observation, and (iii) reflection involving experiment. These reflective experiences are perceived as preparatory to a more deliberate and complex thinking for finding solutions when encountering complex problems. Practical deliberation reflects the kind of thinking done by everyone in daily routines, in which neither the data nor the approach to dealing with them involves anything outside the limits of everyday experience. Reflection upon observation also, relies on every day and unspecialised experience, but the problem rather than being directly linked with the person's business, arises indirectly out of his/her activity, and so tends to be more theoretical and reflect impartial interest. The reflection involving experiment on the other hand, is a reflective experience which is unlikely to occur without prior experience in scientific thinking.

The process of thinking is triggered when we encounter a situation or a problem which comes with a significant need for a solution. The experience begins with an unknown or incomplete understanding of the situation which could be due to inadequate knowledge of the subject matter. This experience could lead to a haphazard action to solve the problem, which could result in unintended outcome. In an engineering context, this could lead to a technical disaster which could be fatal to the public, affecting environment and cost. Therefore, reflective thinking could avoid haphazard action to solve a problem.

In ACAT the reflective experience involves five logical distinct steps: (i) a felt difficulty, (ii) its location and definition, (iii) suggestions about a possible solution, (iv) the rational elaboration of an idea, and (v) further observation and experiment. Any arising issue or conflict is identified by first finding out its position within the context, and then reformulating it to achieve the intended result. The suggestion of possible solutions involves inferencing, which is also termed supposition, guessing, and hypothesising, and in more elaborate cases is known as theory. This stage of reflective experience which allows the postponement of a conclusion pending further evidence, or suspending judgment, is an important factor in this process of reflective thinking. The final logical step is further observation and experiment leading to the acceptance or rejection of belief or disbelief.

3.2.2 Systematic Inference: Induction and Deduction (SIID)

SIID involves double movement, back and forth between facts and meanings. The first step is to recognise the need for movement towards a suggestion or hypothesis, and movement back to facts. The second step is to recognise the interdependence between reasons and evidence. The double movement in this context moves from, for example, incomplete or confused data to a complete comprehensive situation, and back from this suggested whole (an idea or meaning) to the particular facts connecting these to one another and adding more facts or evidence to which the suggestion has demanded attention. SIID also involves locating un-stated assumptions and looking for assumptions about analogous, or comparable situations, and the appropriateness of a given explanation, to identify whether a conclusion follows from earlier assumptions. This systematic movement involves accepting a working hypothesis as an initial guide to investigate and bring to light new evidence or facts. This building up of the idea or suggestion is known as *inductive discovery*, while the movement toward applying, and trialling and testing the idea or theory is the *deductive proof,* (Dewey, 1910: 81). Deductive proof is used to confirm, refute, or modify the theory, so as to build its capacity to interpret the individual details into a whole unified experience, (Dewey, 1910: 81). This whole process of inductive and deductive movement allows for valid discovery or verified critical thinking.

3.2.3 Judgement: Interpretation of Facts (JIF)

Judgment in this context refers to the systematic assessment and filtration of inferences which leads to good judgement about a situated problem. There are three factors in judging:
(i) controversy, consisting of investigating opposite claims regarding the same objective situation, (ii) a process of defining and elaborating these claims and of filtering the available facts to identify the ones which support them best, (iii) a final decision, bringing a closure to the particular matter in dispute and also identifying guidance or underlying principles as reference points for future decision making.

3.2.4 Meaning: Conceptions and Understanding (MCU)

In scientific thinking, meaning is founded, ‘not on the directly perceived qualities nor on directly useful properties’, but on how certain things are ‘causally', related to each other, (Dewey, 1910: 134). That is, in scientific inquiry, meaning is not derived from lay person’s terms, for example what he/she meant or understood by *glass*. A lay person would probably define it based on what he/she sees and touches. Shiny, transparent, smooth and heavy for its size may probably be included for direct qualities, and for useful properties, it is recyclable without loss in quality. However, in scientific conception meanings are not just perceived based on qualities or properties. What makes up glass? For example, glass is the product of the chemical elements it contains, i.e. silicon dioxide as sand or limestone (mineral). Therefore, a scientific conception requires factual knowledge and information on the subject matter. In scientific thinking and inquiry, any distortion of meaning may lead to a disaster for a technical invention or solution. Scientific meaning could be easily affected mainly in three ways: (i) lack of intellectual knowledge, (ii) intellectual confusion and perplexity, i.e. about specific scientific terms, or, (iii) intellectual perversion; lack of common sense. In scientific thinking, meanings are used to infer and make judgements, leading to continuity, freedom and flexibility in a changing process (Dewey, 1910: 134).

3.2.5 Thought: Abstract, Concrete, Empirical and Scientific (TACES)

In reflective thought, thinking can progress from abstract to concrete. Abstract thinking relies on theory and excludes the practical application of the thinking to resolve a situated problem as in pure sciences. Thinking which requires more thinking is abstract, while thinking which leads to action is concrete. In medical sciences, politics, architecture and engineering, thinking is only complete when it is employed in resolving problems in practical life such as health, justice, well-being, and to achieve the desired outcome involves concrete thinking. Hence, thinking which does not include action or practice is termed as abstract, theoretical, and intellectual.

Nevertheless, abstract thinking, which excludes action could also be justified to be highly practical in a general sense, because having a curious mind with interest in thinking for the sake of thinking, and interest in knowing and acquiring knowledge, in itself is a freedom from a routine life and is more productive and progressive. Concrete thinking on the other hand, which involves practical activities is not only a routine and mechanical kind of thinking, but requires intelligence in discriminating and selecting of means and materials to resolve a practical or a scientific problem. As such, in engineering, abstract thinking is required in acquiring knowledge on the subject matter, while concrete thinking is required in applying knowledge selectively to investigate, leading to acceptance or rejection of a result.

In systematic thinking, which demands a specific outcome, empirical and/or scientific thinking is required. In empirical thinking an outcome is predicted or perceived based on repeated observations, practised beliefs or established doctrines. For example, the use of geometry in maths is actually an example of an accumulation of documented empirical observations by the Greeks about the methods of approximate calculation of land surfaces, which later has been accepted as a scientific form, (Dewey, 1910: 146). In the context of engineering empirical thinking could include acceptance of physics theory, scientific principles, and mathematical concepts which were established by renowned physicians and mathematicians. This is required in engineering where students are expected to learn and understand such domains of knowledge in order to acquire engineering skills.

In contrast to empirical method which can be understood as passive thinking, scientific thinking allows an active approach to seeking factual evidence using analysis and synthesis through experiments to produce a reliable and valid outcome, (Dewey, 1910: 152). This process reduces potential errors and increases the certainty of specific ideas or facts. Though, empirical and scientific methods differ in their approach to thinking, each has its value. Empirical thinking magnifies the established doctrines or, 'influences of the past; the experimental method throws into relief the possibilities of the future' (Dewey, 1910: 154). That is, empirical thinking acknowledges what has been previously established and had been accepted as scientific form, while, scientific thinking is interested in the future for a progressive mind. In engineering education, both these types of thinking help to train students as mature engineers.

Abstract, concrete, empirical and scientific thinking are all important in engineering studies as each of them facilitates student's intellectual development at different stages of learning leading to a mastery of relevant knowledge and skills combined with a positive mental attitude in understanding and resolving engineering problems.

3.3 Dewey's Logical Considerations as a Critical Thinking Conceptual Framework for Foundation Year Engineering

Dewey's Logical Considerations (DLC), have been adopted and adapted into the critical thinking conceptual framework, for this PhD research, mainly, because his ideas are foundational for critical thinking in all disciplines. His ideas emphasise suspending of judgement (ACAT), reflecting on alternatives (SIID), testing hypotheses against facts in both directions (SIID), defining things clearly, (MCU), and making judgments as in to bring closure to a problem or matter in dispute (JIF). His reflective thought includes abstract thinking, which creates curious minds, *concrete thinking* for problem solving with practical and intellectual skills, *empirical thinking* for procedural thinking, and *scientific thinking* through investigation, and process through discrimination (analysis) and assimilation (synthesis), (TACES). These five processes of reflective thinking are relevant to foundation year engineering as they provide the basis for CTs as preparatory skills for their undergraduate engineering programme. A summary of Dewey's Logical Considerations as a conceptual framework for CTs is presented in *Table 3:1* (*on p 44*).

Dewey's reflective thinking correlates with the Subject Benchmark Statement (Engineering) (SBS), (2015), read together with The Accreditation of Higher Education Programmes for Engineering Council UK (AHEP), (2014: 10-13). Subject Benchmark Statement (Engineering), (2015: 7) in mentioning the characteristics of engineering graduates, emphasise, way of thinking, as a generic skill across all engineering disciplines, with logical and practical steps as a necessary approach to be a pragmatic engineer, and this aligns with what has been outlined in Dewey's Logical Considerations.

Similarly, Dewey's general *reflective thinking* appears in AHEP, (2014: 12-14) mainly in the first three broad areas of learning:

Science and mathematics (p 12)

- *Knowledge and understanding of the scientific principles underpinning relevant current technologies, and their evolution*

Design (p 13)

- *Define the problem, identifying any constraints including environment and sustainability limitation; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards*
- *Work with information that may be incomplete or uncertain and be aware that this may affect the design*

Concerning science and mathematics, knowledge and understanding of scientific principles*,* (*on p 12)*, is seen as the key for engineering, and this connects with Dewey's concepts of MCU (*Table 3-1*). Dewey's TACES (*Table 3:1*) provides the basis for conducting analysis in scientific thinking, expected in Engineering Analysis (*on p 12*). Dewey's ACAT (i) and SIID (ii), have some similarities with the key learning areas mentioned in *Design*, though, this is in a generic sense and not in specific engineering and technical context.

Dewey's Logical Considerations, provides the basis for CTs in engineering, as in other disciplines. However, it has two limitations; firstly, it only focuses on the thinking process, and is lacking information on how one could develop the skills as a critical being. Secondly, this conceptual framework was not specifically written for engineering. Therefore, it needs to be complemented with inclusion of the missing two aspects, which are creating a critical thinker, and CTs for engineering as recommended by the expert community. This is achieved by employing Paul, Niewoehner and Elder Engineering Reasoning Model (2006) for developing students as mature critical thinkers and the Conceive Design Implement Operate (CDIO) critical thinking model adapted from CDIO Syllabus version 2.0 (2011).

Table 3:1 Dewey's Logical Considerations (1910) - (Critical Thinking Framework)

<table>
<tr>
<td>The Analysis of a Complete Act of Thought (ACAT)
i. A felt difficulty – identify problem within the given context;
ii. Identify problem location and definition – reformulate the problem;
iii. Suggestions and a possible solution – inferencing, supposition, guessing, or hypothesising (theory);
iv. The rational elaboration of an idea;
v. Further observation and experiment leading to acceptance or rejection of belief or disbelief - conclusion pending further evidence, or suspending judgment.</td>
<td>Meaning: Conceptions and Understanding (MCU)
i. Scientific meaning is not conceived through direct qualities but factual knowledge and information on the subject matter;
ii. Distortion of meaning will lead to a disaster to a technical invention or solution;
iii. Meaning making could be affected mainly by lack of intellectual knowledge; intellectual confusion on specific scientific terms; intellectual perversion (lack of common sense).</td>
</tr>
<tr>
<td>Systematic Inference: Induction and Deduction (SIID)
i. Recognising the movement toward a suggestion or hypothesis and the movement back to the facts – testing hypothesis against facts in both directions;
ii. Recognising the definite connections of interdependence between reasons and evidence – working with incomplete information or confused data;
iii. Locating un-stated assumptions;
iv. Looking for assumptions about comparable situations and appropriateness of a given explanation to identify whether a conclusion follows from earlier assumptions – reflecting on alternatives.</td>
<td rowspan="2">Thought: Abstract, Concrete, Empirical and Scientific Thinking (TACES)
i. Abstract thinking relies on theory, and excludes the practical application of the thinking to resolve a situated problem as in pure science, but it is highly productive and progressive, for it creates a curious mind to actively engage in thinking to acquire knowledge;
ii. Concrete thinking involves practical activities which are not of a routine and mechanical kind, but require intelligence in discriminating and selecting of means and materials to resolve a practical or scientific problem;
iii. Empirical thinking as passive method predicts or perceives outcome based on repeated observations, practised beliefs, or established doctrines;
iv. Scientific thinking allows an active approach to seeking factual evidence through investigation by going through the process of discrimination (analysis) and assimilation (synthesis) to produce a reliable and valid outcome.</td>
</tr>
<tr>
<td>Judgement: Interpretation of Facts (JIF)
i. Controversy, consisting of investigating opposite claims regarding the same objective situation;
ii. A process of defining and elaborating these claims and of filtering the available facts to identify the one which supports them best;
iii. A final decision, bringing closure to the particular matter in dispute; identifying guidance and reference points for future decision making.</td>
</tr>
</table>

3.4 Paul, Niewoehner and Elder Engineering Reasoning Model (2006)

Paul, Niewoehner and Elder's Engineering Reasoning Model (PNE) focuses on the way in which engineers think. It presents a discipline-specific interpretation of critical thinking in Engineering. The earlier version of this model by Paul and Elder (1994) was in a linear, statement form, and was later developed into a critical thinking framework (Paul and Elder, 2002; Paul, 2005: 31) as a generic model for professional development in responding to research claim that, there is lack of any substantive concept of critical thinking among most college faculty (Paul, Elder and Bartell, 1996; 1997). In recent times, this model has appeared in several *Thinkers' Guides* by Paul and Elder, (2014a; 2014b) adapted to various purposes, for example, for international reading and writing, how to read a paragraph, and also adapted to various disciplines. There are more than twenty miniature guides, which also have been translated into several international languages, demonstrating the popularity and wide influence of the model.

The PNE engineering reasoning model, (*Figure 3:1 on p 46*) is divided into three main components; *Intellectual Standards, The Elements,* and *Intellectual Traits*. The first component, *Intellectual Standards,* outlines a set of criteria for evaluating engineering thinking, which are *clarity*, *precision*, *accuracy*, *significance*, *relevance*, *completeness*, *logicalness*, *fairness*, *depth,* and *breadth*. To meet these standards, the information presented or reported regarding any engineering problem needs to be clear, accurate, precise, and relevant to the given problem.

The second component, *The Elements of Thought*, is where the reasoning takes place. A thinking is *purposeful*, within a *point of view* based on *assumptions*, leading to *implications*; evidence used to make *inferences* and *judgement* based on *concepts* and theories to answer a *question* or resolve a problem. The *Elements of Thought* allows one to evaluate how he/she thinks and others think.

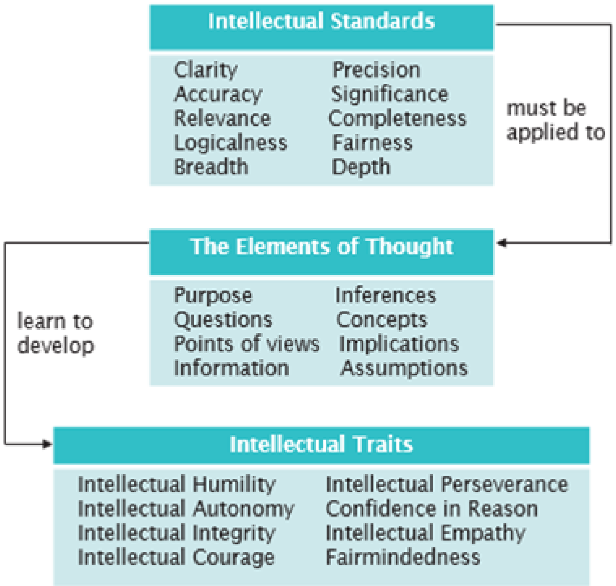


Figure 3:1 Paul, Niewoehner and Elder Engineering Reasoning Model (2006)

The third component is the personal and *Intellectual Traits* to be developed by applying the *Intellectual Standards* to the *Elements of Thought.* Eight intellectual traits are outlined in this model; *Intellectual Humility, Intellectual Courage, Intellectual Integrity, Intellectual Perseverance, Intellectual Empathy, Fairmindedness, Confidence in Reason* and *Intellectual Autonomy*. These traits must be cultivated if students are to become professional engineers, though this takes time and experience. Exposing students to these traits in their engineering courses will be a starting point to cultivate these intellectual traits in the longer term.

In another publication, Niewoehner, (2006) explains how the engineering reasoning model which was further developed with members of CDIO could be adapted for classroom exercises to enhance students reasoning skills in project work, aesthetics, and craftsmanship to develop mature thinking engineers. Further evidence of the PNE model's influence can be seen in work such as that of Claris and Riley, (2012), who made reference to the model in their research on critical pedagogy in engineering. They aimed to incorporate content related to critical theory and reflective judgment, in engineering education believing that this will encourage challenges to power or knowledge, support critique of engineering epistemologies and promote reflexive practice in engineering. In an earlier study, Niewoehner and Steidle, (2009) evaluated the model by applying it in aviation disaster case studies in classroom discussion, and recommended it is an effective model which could be adapted to teach critical thinking across disciplines.

PNE also has some parallelism with (AHEP) (2014), (SBS) (2015). For example, AHEP refers to Engineering Practice, (*on p 14*) focused on Awareness of quality issues and their application to continuous improvement, Awareness of team roles and the ability to work as a member of an engineering team. The document also refers to PNE-related Additional Skills, Plan self-learning and improve performance as the foundation for lifelong learning/CPD, Exercise personal responsibility.

SBS also explicitly states the desired characteristics of engineering graduates, (*on p 7*)

- *be pragmatic, taking a systematic approach and logical and practical steps necessary for, often complex, concepts to become reality*
- *seek to achieve sustainable solutions to problems and have strategies for being creative, innovative and overcoming difficulties by employing their skills, knowledge and understanding in a flexible manner*
- *be risk, cost and value conscious, and aware of their ethical, social, cultural, environment, health and safety, and wider professional responsibilities*
- *be professional in their outlook, be capable of team working, be effective communicators, and be able to exercise responsibility and sound management approaches.*

These traits resonate with PNE's eight intellectual traits in developing highly professional engineers to work in the real engineering world.

Although, PNE outlines the *Intellectual Standards*, and the *Elements of Thought* required to achieve these *Intellectual traits*, it however, is still lacking in defining the specific mode of thinking common in engineering practice. Therefore, the CDIO Critical Thinking Model, adapted from a comprehensive engineering syllabus for undergraduate education was selected to fill in the gap.

3.5 Conceive Design Implement Operate (CDIO) Critical Thinking Model

The Conceive Design Implement Operate (CDIO) critical thinking model is adapted from a comprehensive general Syllabus (Crawley, *et al*., 2011) designed by an international consortium of engineering educators and ratified by diverse international industry and academic leaders. An earlier version of the syllabus was developed by The Massachusetts Institute of Technology (MIT), Kungliga Tekniska Hogskolan (KTH), Chalmers University of Technology and Linkoping University, Sweden, as a reaction to the observation that, engineering science was becoming disengaged from engineering practice in many engineering education institutions, (Crawley, 2001; Edstrom and Kolmos, 2014). Crawley, (2001) a member of the CDIO consortium, explains that the need for a general syllabus is to summarise formally a set of technical knowledge, skills and attitudes that, students must command to be able to be functional in the real engineering world, and to produce real *products and systems*. For Crawley, engineering education in recent times has become, 'disassociated' from actual engineering practice. The original CDIO model was designed on the assumption that, *Graduating engineers should be able to **c**onceive-**d**esign-**i**mplement-**o**perate complex value-added engineering systems in a modern team-based environment*, (2011: 14).

The second version of the CDIO syllabus was developed in line with the UNESCO Four Pillars of Learning, (Delors, 1996) and the national accreditation schemes of several nations such as the Canadian Engineering and Accreditation Board (CEAB), (2010), Accreditation Board of Engineering and Technology, Criteria for Accrediting Engineering Programs (ABET) United States (2010), the Swedish national requirements for engineering degrees, European EUR-ACE accreditation for engineering programmes, and the British UK-SPEC (cited in Crawley, *et al*. 2011). The revised version made some modifications so that it corresponds with the national accreditations to reflect a broader view of engineering practice. The modifications include the addition of a range of CTs, *(2.1.) Analytical reasoning and Problem Solving*, *(2.5.1) Ethics, Integrity, and Social Responsibility*, and *(3.1.5) Multidisciplinary Teaming*, (*Appendix A: p 269*).

The CDIO syllabus v2.0, provides comprehensive guidelines in identifying the relevant CTs required for an undergraduate engineering programme. *Table 3:2* shows the core CDIO critical thinking model, section 2 and 3, *Personal, and Professional Skills and Attributes (2)* and *Interpersonal Skills: Teamwork and Communication (3)*. Section 1, *Disciplinary Knowledge and Reasoning* and section 4, *Conceiving, Designing, Implementing, and Operating Systems in the Enterprise, Societal and Environmental Context – The Innovation Process* were not selected because they are more focused on knowledge and technical skills rather than specifically on CTs.

The selected section in the condensed CDIO syllabus v2.0, *(Appendix B on p. 272)* has five learning objectives: The first three objectives: *Analytical Reasoning and Problem Solving (2.1), Experimentation, Investigation and Knowledge Discovery (2.2.), and System Thinking (2.3)*, are described as the three modes of thinking commonly practised in engineering (Crawley, *et al*., 2011). The remaining two, *Attitudes, Thought and Learning (2.4)* and *Ethics, Equity and Other Responsibilities (2.5)* generic skills needed for developing engineering intellectual traits.

Table 3:2 CDIO Critical Thinking Model (adapted from CDIO Syllabus version 2.0, Crawley et al., 2011)

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION**
2.1 ANALYTICAL REASONING AND PROBLEM SOLVING 2.1.1 Problem Identification and Formulation 2.1.2 Modelling 2.1.3 Estimation and Qualitative Analysis 2.1.4 Analysis With Uncertainty 2.1.5 Solution and Recommendations **2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY** 2.2.1 Hypothesis Formulation 2.2.3 Experimental Inquiry 2.2.4 Hypothesis Test and Defense **2.3 SYSTEM THINKING** 2.3.1 Thinking Holistically 2.3.2 Emergence and Interactions in Systems 2.3.3 Prioritization and Focus 2.3.4Trade-offs, Judgment and Balance in Resolution **2.4 ATTITUDES, THOUGHT AND LEARNING** 2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility 2.4.3 Creative Thinking 2.4.4 Critical Thinking 2.4.5Self-awareness, Metacognition and Knowledge Integration 2.4.7 Time and Resource Management **2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITY** 2.5.1 Ethics, Integrity and Social Responsibility 2.5.2 Professional Behavior 2.5.3 Proactive Vision and Intention in Life	**3.1 TEAMWORK** 3.1.1 Forming Effective Teams 3.1.2 Team Operation 3.1.5 Technical and Multidisciplinary Teaming **3.2 COMMUNICATIONS** 3.2.1 Communications Strategy 3.2.2 Communications Structure 3.2.3 Written Communication 3.2.4 Electronic/Multimedia Communication 3.2.5 Graphical Communication 3.2.6 Oral Presentation 3.2.7 Inquiry, Listening and Dialog 3.2.8Negotiation, Compromise and Conflict Resolution 3.2.10 Establishing Diverse Connections and Networking **3.3 COMMUNICATIONS IN FOREIGN LANGUAGES** 3.3.1 Communications in English 3.3.2 Communications in Languages of Regional Nations 3.3.3 Communications in Other Languages

Section 3, the *Interpersonal Skills: Teamwork and Communication* is another generic critical thinking component which is not restricted to engineering. However, these include *Teamwork (3.1.)*, *Communications (3.2)*, and, *Communications in Foreign Languages (3.3)*, and these are also related to section 2 *Personal and Professional Skills and Attributes* with its focus on interaction with others.

The adapted CDIO Critical Thinking Model covers the specific CTs for engineering, most relevant particularly for foundation level. Niewoehner, (2006) and Sale and Cheah, (2011) have adapted different versions of the CDIO syllabus into a critical thinking model to teach the skills to engineering students. Sale and Cheah, (2011) selected *2.4 Attitudes and, Thought and Learning* from section 2, *Personal and Professional Skills and Attributes* to teach critical thinking explicitly to chemical engineering students , using simulations with positive results. Niewoehner, (2006) combined the CDIO syllabus version 1.0 with the Paul and Elder (2003) critical thinking model to outline a systematic approach to teach critical thinking using real engineering failures, case study on aviation disasters. This suggest that the CDIO syllabus is comprehensive and versatile enough to be customised to teach critical thinking to any particular engineering discipline.
The CDIO syllabus also has two distinctive elements, which are teamwork and communications. Engineers do not work in isolation, but as a team to work on engineering projects, or products, and for this, communication is the key. This aspect of the model adds value to the blended framework, as these components are not found in Dewey or PNE.

3.6 A Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering

This research incorporated the three different critical thinking models, Dewey's (DLC), PNE, and the CDIO as a Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering, (*Figure 3:2 on p 51*). An analysis of the three models showed some overlaps, however, there are some distinctive elements in each one, which have contributed to developing the Blended Conceptual Framework for Critical Thinking for foundation year engineering. Dewey's general idea of critical thinking such as the ACAT (v), *suspending judgement*; SIID (i) *testing hypotheses against facts in both directions*, (ii) *working with incomplete information or data*, (iv) *reflecting on alternatives*, and TACES (iv) *investigation thorough discrimination (analysis) and assimilation*
(synthesis), are the original elements of critical thinking which are repeated in PNE and CDIO in an engineering context. However, *suspending judgement* and *testing hypotheses against facts in both directions* are not explicitly stated in either PNE or CDIO. Therefore, Dewey was made as a reference point for general CTs for designing the research and analysing the data.

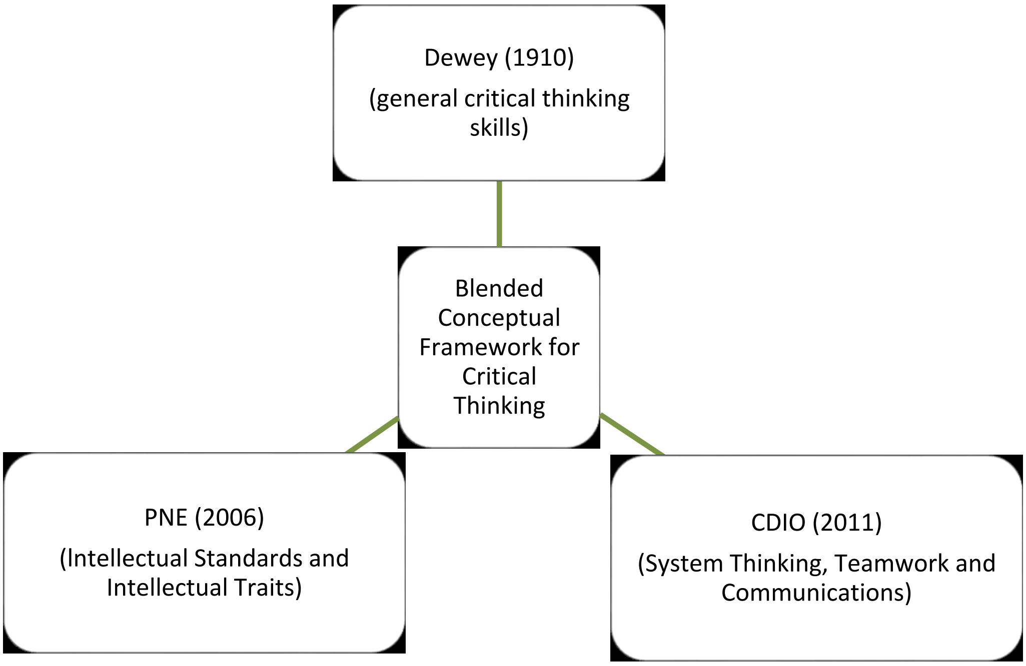


Figure 3:2 The Blended Conceptual Framework for Critical Thinking for Engineering Foundation Year

PNE on the other hand, focused mainly on the learners as *critical beings*, rather than the skills in developing engineers with intellectual traits. However, the *Elements of Thought* of PNE define the process of thinking similar to DLC. The *Intellectual Standards* and *Intellectual Traits* are unique to PNE, with some resemblance to CDIO in section 2 on developing personal and professional skills and attributes for engineers. Though CDIO also has some similarities with the other selected models, its system thinking in section 2 and teamwork and communications in section 3 did not appear either in DLC or in PNE as such they were selected for the blended framework because these skills are essential in engineering practice. Each model selected for the blended framework was then analysed for its compatibility with the UK accreditation for engineering to validate its relevance to be used for the foundation year in engineering. The analysis showed the blended model was compatible in almost all the six key learning outcomes as shown in *Table 3.3* (*on p 52*). CDIO has the highest compatibility as an engineering critical thinking model, followed by PNE, and DLC as a general critical thinking model.

Table 3:3 The Accreditation of Higher Education Programmes for Engineering Council, UK with the Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering

The Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence (2014: 12-14)	DLC	PNE	CDIO
1. Science and mathematics			
• Knowledge and understanding of the scientific principles underpinning relevant current technologies, and their evolution	MCU		2.2, 2.3, 2.4.5
2. Engineering analysis			
• Ability to monitor, interpret and apply the results of analysis and modelling in order to bring about continuous improvement	TACES (iv)	INTELLECTUAL STANDARDS	2.1.2
• Ability to apply quantitative methods in order to understand the performance of systems and components			2.3.2
• Ability to use the results of engineering analysis to solve engineering problems and to recommend appropriate action			2.1.5
• Ability to apply an integrated or systems approach to engineering problems through know-how of the relevant technologies and their application.			2.3.2
3. Design			
• Be aware of business, customer and user needs, including considerations such as the wider engineering context, public perceptions and aesthetics		ELEMENTS OF THOUGHT	2.4.3
• Define the problem, identifying any constraints including environmental and sustainability limitations; ethical, health, safety, security and risk issues; intellectual property; codes of practice and standards	ACAT (i), (ii)	ELEMENTS OF THOUGHT	2.1.1
• Work with information that may be incomplete or uncertain and be aware that this may affect the design	SIID (ii)	ELEMENTS OF THOUGHT	2.1.4
• Apply problem-solving skills, technical knowledge and understanding to create or adapt design solutions that are fit for purpose including operation, maintenance, reliability etc.,		INTELLECTUAL STANDARDS	2.4.2
• Manage the design process, including cost drivers, and evaluate outcomes			2.4.7

The Accreditation of Higher Education Programmes: UK Standard for Professional Engineering Competence (2014: 12-14)	DLC	PNE	CDIO
• Communicate their work to technical and non-technical audiences.			3.2.1
4. Economic, legal, social, ethical and environmental context • Understanding of the need for a high level of professional and ethical conduct in engineering and a knowledge of professional codes of conduct • Knowledge and understanding of the commercial, economic and social context of engineering processes • Knowledge of management techniques that may be used to achieve engineering objectives • Understanding of the requirement for engineering activities to promote sustainable development • Awareness of risk issues, including health & safety, environmental and commercial risk.		INTELLECTUAL TRAITS ELEMENTS OF THOUGHT INTELLECTUAL TRAITS INTELLECTUAL TRAITS	2.5.1 2.5.1 2.4.5, 2.4.7 2.5.1 2.5.1
5. Engineering practice • Ability to use appropriate codes of conduct of practice and industry standards • Awareness of quality issues and their application to continuous improvement • Awareness of team roles and the ability to work as a member of an engineering team.		INTELLECTUAL TRAITS INTELLECTUAL TRAITS	2.5.1 2.4.2 3.1.1
6. Additional general skills • Apply their skills in problem solving, communication, information retrieval, working with others and the effective use of general IT facilities • Plan self-learning and improve performance, as the foundation for lifelong learning/CPD • Exercise personal responsibility, which may be as a team member.		INTELLECTUAL STANDARDS INTELLECTUAL TRAITS INTELLECTUAL TRAITS	2.1.1, 2.4.4, 2.4.5, 3.1.1, 3.2.4, 3.2.8 2.4.1 3.1.2

However, the blended conceptual framework has its limitations as it is developed on theoretical grounds without empirical research. The skills referred in the framework are the skills that the educators want the students to acquire, and not necessarily the actual skills required by students in their undergraduate engineering.

In sum, the blended framework for CTs need to be evaluated through research into students' starting knowledge and experience, and thus their actual needs. This study will contribute to this through an exploration of the relevance of the framework to engineering foundation programmes with diverse intakes, through qualitative study of case study participants including international students, European students, UK and US students, mature students, and a student with disability.

3.7 Conclusion

Development of engineering students' CTs in their undergraduate study is important for their personal and intellectual development, as well as for their future career success as engineering professionals. To explore this issue, it was important to carry out empirical research into students' developing understanding of CTs, module instructors' perceptions about the skills, and in what ways current educational practices affect students' ability to think critically, with reference to an overarching conceptual framework of CTs, and the framework adopted in this study has been introduced in this chapter.

The three critical thinking models, DLC, (1910), PNE, (2006) and CDIO, (2011) will be briefly discussed together with the blended framework for critical thinking for foundation year with reference to the design of the study in chapter 4 methodology, will be used in chapter 5, 6 and 7, the findings chapters to support analysis of the data, and will be evaluated in chapter 8 in a final discussion.

Chapter 4 Research Methodology

This chapter presents the methodology used in the present study and the rationale for employing the selected research design for answering the research questions to respond to the study inquiry. The research design is described and justified as suitable to investigate the development of critical thinking skills (CTs) of Engineering Foundation Year (EFY) students. In addition, a more detailed description of the context of the study, setting, and research participants is given. Then, the research instruments and data collection procedures are explained. Finally, an overall account of ethical management of the research methodology is provided.

4.1 Research Aims and Research Questions

The purpose of the study is to understand the nature of the general and subject-specific critical thinking skills for engineering education, and investigate how the current curriculum and the practice within the programme address the expectations and learning needs of foundation engineering students to develop these skills.

The research is guided by the following aims:

I. To investigate engineering foundation year students' understanding and attitude towards critical thinking skills taking account of their first language, previous learning experiences, and their cultural background at the beginning and end of the programme. (Research Questions: 1, 4, 5)

II. To investigate the relationship between teaching and learning practice within the foundation year programme, and the development of critical thinking skills among students. (Research Question: 2)

III. To find out faculty's perception of critical thinking skills for engineering based on module instructors' definition of critical thinking skills and analysis of foundation year course documents. (Research Question: 3)

IV. To design a blended conceptual framework for critical thinking for Engineering Foundation Year (EFY)

The research is further guided by the following research questions:

Research Question 1: What are engineering foundation year students' perceptions and attitudes towards critical thinking skills at the beginning and at the end of the programme?

This question aimed to capture students' development in their conceptualisation of critical thinking skills within the Engineering Foundation Year (EFY). To monitor students' progress in CTs the study used a longitudinal approach to gather the data over a period of a year from the beginning of Semester Two of the EFY programme to beginning of Semester Two of the Year 1 undergraduate programme, through tracking case study students at a British University (University X). Longitudinal data collection was needed because the development of critical thinking skills requires sufficient training or experience of critical thinking tasks for a period of time, (McPeck, 1990; Halpern, 1997; McBride*,* Xiang and Wittenburg, 2002).

Research Question 2: How do students learn and develop their critical thinking skills in the Engineering Foundation Year (EFY) programme?

a) To what extent do students have the opportunity to practise critical thinking skills in the Engineering Foundation Year programme?
b) What types of critical thinking skills are students exposed to during the foundation year?
c) To what extent does students' prior learning influence their ability to learn and apply the skills in their foundation engineering study?

Teaching and learning approaches are believed to have direct influence in students' critical thinking development. For example, research on instruction such as that on explicit teaching by Abrami, *et al.*, (2008) and on problem-based learning by Tiwari, *et al*., (2006) suggests that constant exposure to critical thinking tasks promotes critical thinking. Hence, this research aimed to find out what types of exposure students received to practice and develop their critical thinking skills in their foundation year in preparation for their undergraduate programme. It was hypothesised that students at foundation level will be exposed to both some generic skills and also subject specific critical thinking skills for engineering to equip them for their undergraduate engineering programme. The case studies carried out at University X provided data for these questions.

Research Question 3: What is faculty's (lecturers') goal for students' critical thinking skills?

a) Are critical thinking skills evident in general curricula for the discipline of engineering foundation year, and in module profiles and other documents? If yes, what types of skills are given preference?

b) How do the foundation year module instructors define critical thinking skills and how does this influence their pedagogical choices?

Educational practices have direct influence on students' learning. Barnett, 1997; Paul, 2005, and de Jager, 2012), argue that educators require substantive understanding of critical thinking to help students turn to acquire substantive knowledge and skills in critical thinking. It was therefore important to explore the understanding of module instructors in EFY.

The above research questions were investigated by looking at the established documentation on critical thinking skills in general and subject-specific critical thinking skills for engineering including: AHEP (2014), the SBS (2015), an up-dated Statement of Goals for Undergraduate Engineering Education, the international engineering syllabus *Conceive Design Implement Operate* (CDIO) Syllabus v2.0 (2011) and the Thinkers Guide to Engineering Reasoning by Paul, Niewoehner and Elder, (2006). These curriculum statements and literature were checked against the Faculty of Engineering course documents, (2014-15) of two British universities, primarily University X the main case study site, and also University Y as a supplementary source for document analysis and module instructors' interview responses.

Furthermore, there was a need to find out how the faculty accommodates to students' needs to practice and develop the critical thinking skills. This was explored in two ways, firstly, by finding out through interviews and documentary analysis to what extent students had the opportunity to practise these skills in the teaching and learning environment. Secondly, by exploring through individual interviews the module instructors' views and perceptions on critical thinking skills and how these influenced their instruction.

Research Question 4: Does a student's cultural background affect his/her ability to learn and apply critical thinking skills?

As for the students' prior learning it was expected that their previous experience could facilitate, or hinder the development of their critical thinking skills, as they were understood in a British higher education context. Authoritarian education systems and, or the pressure for conformity within particular cultures may not have provided opportunities for students to practice critical and analytical skills in their prior learning, (Brown, 1998; Yim *et al.*, 2000; Minakova, 2014; Shaheen, 2016). This could also lead to students from such educational, or cultural backgrounds becoming passive and rote learners, (Mangena, 2003; Manola *et al*., 2013). Therefore, this research aimed to find out whether prior learning and cultural background influenced the case study students in learning and applying the skills in their engineering study; if yes, what were the contributing factors and, if not why they did not affect them.

Research Question 5: To what extent does language play a role for students in learning and applying critical thinking skills?

Engineering education is delivered in English more widely in most parts of the world, therefore, the study also looked into the possible influence of language in the development of critical thinking ability in a second language (L2) medium setting, because from the ten students who participated in the research, six were non-native speakers of English. Some studies have shown the use of a second language (L2) has a detrimental effect on students' repeated cognitive performance. For example, the works of Koda, (2007) on discourse processing and Kirby, Woodhouse and Ma, (1996) on deep-learning processes suggest that lack of second language proficiency can influence students' ability to use higher order thinking skills. Takano and Noda, (1993), also claim that Japanese native speakers underperform using English language in cognitive tasks. Conversely, the same case was noted with native speakers of English who performed poorly as well, when using Japanese to carry out linguistics tasks. These studies suggest that the use of L2 could cause a temporary decline of cognitive ability as result of an increase in the processing load.

However, the present study is not focused centrally on the language issue, due to limited access to students formally recognised as having lower English skills (and following a so-called Language Pathway programme). The research was only able to investigate voluntary participants who were above the threshold set by the university for the Pathway Programme, except for one non-native student who was noted to be equally competent to the other participants. The students came from varied educational backgrounds, and most non-native students had access to westernised education. While views from three different groups of students were investigated, i.e., international, European and native students from the UK and USA, the language question could be investigated only to a limited extent.

4.2 Research Design

The research design originally used both quantitative and qualitative methods for methodological triangulation. The quantitative approach used on-line questionnaires to survey students' CTs at different points in the EFY, but a positive decision was finally made to exclude the data, because the questionnaire suffered too much from participant attrition. Therefore, this is primarily a qualitative longitudinal study based on semi-structured interviews with case study students and module instructors, and course documents. This present study, however, still using the mixed research instruments to address the research questions. The triangulation of different kinds of data collected using the mixed instruments expected to reduce discrepancies in data and to provide a broader explanation of the issues under investigation, (Baker, 1994; Bogdan and Biklen, 2003; Blaikie, 2010; Bryman, 2012). It was important that more than one research instrument, or source of data was used , so that findings could be cross checked for credibility and validity of data, (Patton, 2001; Dornyei, 2007; Bryman, 2008).

As for the main research design, it was built using top down approach guided by existing critical thinking literature in general and specifically that for engineering education. On the other hand, the data was analysed using both top down and bottom up approaches.

4.2.1 Research Theoretical Framework

The present research is a longitudinal exploratory study, therefore it was challenging to employ any one specific theory to design and operationalise the research. The main focus was to investigate the development of critical thinking of EFY students, and to what extent the faculty supports and prepares them for their destination undergraduate engineering programme. As such the research needs to analyse: (i) critical thinking theory, (ii) critical thinking instruction, and (iii) students' development of critical thinking skills for engineering. Besides that, the empirical data had different emerging issues. Hence, the research needed to be explored using multiple perspectives and approaches. Therefore, the present research adopted a conceptual framework (*Figure 4:1*), which is a combination of multiple theories, to conduct the research inquiry.

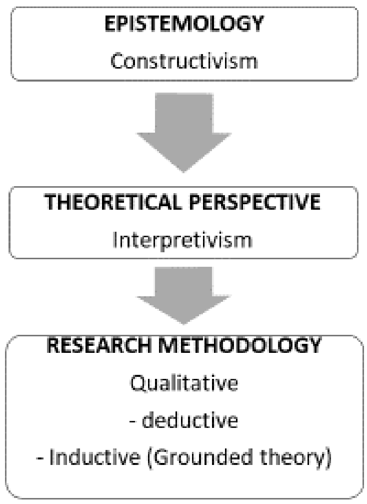


Figure 4:1 Theoretical Perspective and Research Methodology

The conceptual framework was in agreement with the study researcher's philosophical stance, *pragmatism*, an approach in which multiple views may be chosen to best enable answering the research questions to respond to the study inquiry. This means that the philosophical framework of the study concerning epistemology (theory of knowledge), is based on constructivism (data collection), and the theoretical perspectives adopted for data analysis is interpretivism (data analysis) as depicted in (*Figure 4:1 on p 59).* Constructivism permits the construction of new conceptualisations and interpretations of what critical thinking skills are, arising from accounts of the direct experience of students.

The study adopted a deductive approach, firstly to design the conceptual framework, (Imenda, 2014) for CTs already presented in Chapter 3 (*on p 37*), and to analyse course documents in the light of the designed critical thinking framework. On the other hand, grounded theory, which is rooted in the inductive approach was used to analyse the semi-structured interviews, that is, to study students' experience in learning and acquiring the CTs skills during their EFY. Secondly, to collect the module instructors' views on how the course is designed to aid students to learn and develop CTs.

The central principle of the grounded theory aims to explain a process by constantly comparing emerging differences and similarities within a given space and time, (Strauss, 1995; Patton, 2001; Lingard, Albert and Levinson, 2008: 459), for example, students' learning experience. In this case, grounded study is appropriate for main two reasons. Firstly, the exploratory nature of the study has potential for producing new emerging issues, which could further inform the study to either consolidate or challenge the initial research findings, and could also shed new light on areas of study in critical thinking and EFY, which have not been thoroughly explored before. Secondly, EFY students' progress in CTs at three different stages over a period of a year can best be captured through grounded theory, as this could help to formulate the distinctive meaning of CTs within a particular learning context. Besides that, tutors' views and perceptions on critical thinking definitions and instruction could help in conceptualising core critical skills in engineering education.

4.3 Context of the Study

The study investigated the development of critical thinking skills of EFY students studying in the UK. The EFY is a one-year preparatory course, prior entry to Bachelor of Engineering (BEng) or Master of Engineering (MEng) degree programmes. It is also known as a pathway programme, offered to both UK and overseas students who do not meet the requirements for straight entry into a bachelor degree in engineering. As such, the EFY programme provides opportunities for students to equip themselves with the necessary academic skills and knowledge required for undergraduate study in the UK.

According to the website of University Foundation Courses UK (2017), there are five main situations where students have to enrol in the Engineering Foundation Year (EFY). Firstly, students who have followed a British curriculum might have taken A-Levels that do not qualify them for the degree they want to study, for example they are applying for BEng Computer Science, but did not do Mathematics A-Level. The Engineering Foundation Year (EFY), offers Mathematics as a compulsory subject/module to qualify them for a bachelor degree in engineering. Secondly, students might not have the grades required to go straight on to the degree course, however, offers are sometimes lower for foundation years, and students who have underperformed at A-Level could achieve their goal to complete a degree course in engineering through this pathway. Thirdly, again in the UK context, students might have a qualification, which does not fulfil the requirement for the engineering course that they want to study, such as Business Technology Education Council (BTEC) (UK), so, they are required to enrol in EFY. Overseas students who have studied a non-British curriculum, but wish to pursue a degree at a UK university, may be required to study EFY as a preparatory course to familiarise them with British academic culture. Finally, international students who scored below 6.5 in International English Language Test System (IELTS), and need additional English language support and academic preparation for entry onto a UK university undergraduate course have to complete an EFY programme.

Upon successful completion of the EFY programme, students are given automatic progression to their undergraduate degree course. A wide range of Bachelor of Engineering (BEng) and Master of Engineering (MEng) degrees is offered upon completion of EFY, including Aeronautics and Astronautics, Acoustical Engineering, Aerospace Electronic Engineering, Biomedical Engineering, Civil Engineering, Computer Science, Geophysics, Mechanical Engineering, Mechatronic Engineering and Ship Science, Software Engineering (foundation year webpage of University of X and University Y). The EFY programme is structured as a 3-semester programme. It is conducted through a variety of teaching modes, such as lectures, laboratory work, workshops and tutorials. Students are also learning academic English and acquiring personal development skills through independent and reflective learning. Besides that, international students who do not meet the English language requirement of IELTS with a score 6.5 or equivalent are provided with English Support classes through Language Pathway programmes which are offered both in the first and second semester.

In the context of this study, EFY students who participated in the research were foundation year students on their one-year preparatory course for entry to BEng or MEng degree programmes.

4.4 Setting

The universities participated in this research on a voluntary basis upon a formal invitation. Eight UK universities were invited via e-mail, and six responded, however, two eventually volunteered to participate (University X and University Y, one from northern England and the other from southern England). UK institutions were chosen because of their cultural diversity with UK, European, Middle-Eastern and Asian students, the latter mostly from China, Taiwan and Japan. The research originally selected University X and University Y as the inclusion of two universities could create an opportunity to establish a degree of comparison on the data collected. However, only University X finally agreed to both students and tutors' participation, and there were no student participants from University Y. Since the primary focus of the study was to investigate students' development in CTs, and without any data from students at University of Y, the main focus of this thesis rests on University X. However, documentation from University Y and module instructors' views are drawn upon when answering Research Question 3 (see *section 1.4 on p 4*).

4.5 Research Participants

This initial aim of the research was to involve EFY students from the Language Pathway who did not meet the university language requirement as well as those who are proficient in the language, from both University X and University Y. However, it was quite challenging to find student volunteers for the study. Eventually the students who volunteered were only from University X, with, four Europeans (including one with hearing disability from language support programme), three UK native students, two international students, and one native USA student, in total ten participants. The international and European students were mostly fluent in academic English. As for the module instructors, a total of ten participated, eight from University X and two from University Y. An attempt had been made to give each member of the population an equal chance of being selected by seeking volunteer students from the complete 2014/15 cohort. The research included as much variety as possible on a voluntary basis, for example on nationality, gender, age, culture and disability. For nationality, the students were from eight different countries, Bahrain, Libya, Latvia, Poland, Greece, Cyprus, United States of America (USA) and United Kingdom (UK). On gender, both males and females were given the opportunity, as were both young and mature students, and one disabled student participated in the research.

4.5.1 Student Participants

The original research plan was to focus on critical thinking development of EFY students from English language pathway programmes to investigate to what extent language and culture affect second language (L2) learners' CTs. Besides that, the research was also interested in finding out how far academic literacy (academic English) affects participants' CTs. However, due to limited access to students from the language pathway programmes except for one participant, the study only had the opportunity to deal with students who had been judged to be above the language threshold set by the university.

Potential participants were first approached by joining one of the teaching sessions at the selected universities. A Power Point presentation was given to provide an overview of the research, and the importance of partcipants' contribution.The students were encouraged to participate on a voluntary basis. A Consent Form (*Appendix E on p 273*) and Participant Information sheet (*Appendix F.1 on p 274*) were sent to students' university mailing addresses with the Director of the FY programme's approval (email copy to EFY Programme Director (*Appendix C on p 271).* In addition to this, an approval was also obtained from both the engineering and language support module tutors to brief the students about the research at computer labs and after classes, (*Appendix D on p 272*). Many students were happy to participate in the qualitative study when approached in person. They had many questions to ask, and were satisfied when a brief overview, and the rationale of the research were given. Student participants who volunteered to participate in the interview were then contacted via e-mail and text message for an informal meeting, *(Table 4:1)* shows summary details of the 10 students who participated in the interviews, including 9 males and 1 female from University X.

Table 4:1 Summary of Interview Student Participants

SEMISTRUCTURED INTERVIEWS	**PARTICIPANTS**		
	International (I)	**European (EU)**	**UK and USA**
Stage One Stage Two Stage Three	1. SS01_M_I (Bahrain) 2. SS02_M_I (Libya)	1. SS06_M_EU (Greece) 2. SS07_M_EU (Poland) 3. SS08_M_EU (Latvia) 4. SS09_M_EU (disabled student) (Cyprus)	1. SS10_M_UK 2. SS11_F_UK 3. SS12_M_UK 4. SS13_M_USA

Students were grouped as European students, International students and UK/USA, as shown in (*Table 4:1).* Such a small sample could not be judged fully representative of the FY population. However, the sample did include one female student and two mature students, as well as a student with hearing impairment who volunteered to participate. The demographic characteristics of the student sample for the semi-structured interviews is as in (*Table 4:2 on p 64).* Students Profiles (*Appendix G on p 278)*.

Table 4:2 Demographic Information of Student Interview Participants from University X

Total number = 10	
Profile	**Total Number**
Gender	
Male	09
Female	01
Age	
18 – 24	07
25 – 32	02
33+	1
First Language	
European (Latvian, Greek, Polish and Cyprus)	04
Arabic (Libyan, Bahrain)	02
English (British)	03
American English (USA)	01
Language used to socialise	
English	10
Previous Education	
State School (UK)	02
Public Funded School (overseas)	05
Private International School (overseas)	02
Private Girls School (UK)	01
English Proficiency Test (IELTS)	
Yes	06
No	04
Disabilities (Hearing impairment)	
Yes	01
No	09

To capture the actual development of critical thinking skills among students over the period of a year the interviews were arranged to be conducted in three stages, Stage One, in February 2015, Stage Two, in May to June 2015, and Stage Three, in February to March 2016. However, the Stage

3 interview collection took longer than anticipated, for students were busy with coursework and projects in their undergraduate programme. Therefore, some of these interviews took place in April 2016. The researcher had planned to have two individual interview sessions and one focus group for Stage 3. Therefore, a trial session was conducted to discuss the general topic of study progress. It was observed during the session that a few students became withdrawn and passive without any critical engagement to challenge others' view points. Hence, a decision was made by the researcher to conduct all the sessions as one to one interviews, and in pairs only when requested.

4.5.2 Module Instructors

The second source of data was semi-structured interviews with EFY module instructors, eight from the University X, and two from Univeristy Y as shown in (*Table 4:3*). The module instructors were invited via e-mail and in person to participate in interviews. Prior to the interview, the Consent Form (*Appendix E on p 273)* and Participant Information sheet (*Appendix F.2 on p 276*) were sent via e-mail to provide an overview of the research.

Table 4:3 Summary of Module Instructors of University X and University Y

Faculty/Discipline	**Module Instructors (MI) and module taught**	**Experience in EFY**	**Gender**	**Native (English)**
Engineering	MI01 – Maths A and B (MT)/University X	13 years	Female	No
	MI02 – Computer Application Coursework (CW)/University X	3 years	Male	Yes
	MI03 – Workshop (WS)/University X	20 years	Male	Yes
	MI04 – Engineering Principles (EP)/University X	6 years	Female	No
	MI05 – Mechanical Sciences (MS)/University X	8 years	Male	Yes
	MI07 – Electronics and Electricity (EE)/University Y	1 year	Female	Yes
	MI09 – Maths (MT)/University Y	1 year	Male	Yes
	MI10 – Electrical Engineering (EE)/University X	7 years	Male	Yes
Humanities/ Department of Modern Languages and Linguistics	MI06 – Language Pathway A (PWA)/University X	1 year	Female	Yes
	MI08 – English for Scientists and Engineers (EES)/University X	7 years	Female	Yes

There was a gender balance between male and female participants. From the ten participants, eight were from Engineering Faculty, and two from the Department of Language and Lingustics, the Humanties Faculty. The participants' experience in EFY, ranges from one to twenty years involvement through various roles; teaching, course designing, programme development, programme leadership, and others. Eight instructors were native speakers of English, and two non-native speakers of English participated in the interviews.

4.6 Research Instruments and Data Collection Procedures

A mixed set of instruments was used to collect data for the research. The rationale for using data from multiple sources was to avoid methodological bias, (Podsakoff MacKenzie and Lee, 2003; Howard, Tang and Austin, 2015).

4.6.1 Interview Protocols

Interview was a primary source of data for this research. For decades, the interview has been one of the most favoured research tools in qualitative empirical research, because it is theorised as useful in investigating and directly reporting people's perceptions, experience, beliefs, attitudes, and values, or their thoughts and feelings about something, or the phenomenon under investigation as claimed by Drever, (1995); Rapley, (2001: 2007); Richards, (2003); Mackey and Gass, (2005); Talmy, (2010). In this case, it provides data on both students and module instructors' perceptions on critical thinking skills, students' experience in learning the skills, and that of module instructors in teaching them. There are several types of interviews, which largely can be classified into two main types, structured interviews and unstructured interviews. In a structured interview, the interviewer controls the conversations with questions guided by identified themes and the response role rests with the interviewee, unlike an unstructured interview, where the interviewee is the main source of both questions and answers, (Hannabuss, 1996; Fontana and Frey, 1998; Alvesson and Deetz, 2000; Rubin and Rubin, 2008; Kvale and Brinkmann, 2009).

The semi-structured interview is a midpoint between structured and unstructured interview approaches. It involves the interviewer deciding in advance, what themes are to be covered and what main questions are to be answered, while additional specific details or structure will be determined during the interview, (Drever, 1995; Alvesson and Deertz, 2000: 194; Hove and Anda, 2005; Irvine and Sainsbury, 2012). On the other hand, the interviewee has the freedom to respond at some length and to answer in his or her words, and the interviewer sustains the interview with probes and prompts. The purpose of probes and prompts in interview are to assist or encourage the interviewee to say what he or she wants to say, (Doyle, 2004). The interviewer uses probes to elicit a more elaborate response asking for clarification and explanation of the comments made, or for defence or justification of a point raised in the interview, (Drever, 1995; Alvesson and Deertz, 2000), for example in-depth exploration of student's learning experiences and critical thinking skills. Through prompting, the interviewer can elicit information on what the interviewee knows but has not mentioned, (Drever, 1995: 23; Kvale and Brinkmann, 2009) such as factual information about previous schooling. For the purpose of this study, semi-structured interview was selected to explore students and module instructors' perceptions and experiences in CTs in the Engineering FY context.

In the existing literature on critical thinking skills research, the empirical findings are largely quantitative, (Tsui 2002; Brumfit, *et. al*., 2005; Johnston, *et al*., 2011) using self-report survey on critical thinking experience or pre-test and post-test on critical thinking dispositions with limited use of research interviews which focus on the topic in-depth with qualitative data. Some exceptions are the interview research on critical thinking skills and applied linguistics by, Brumfit, *et al*., (2005) and Johnston, *et al*., (2011), who investigated the development of criticality among undergraduates in Modern Languages, and Social Work in the UK. Moore, (2011), investigated, critical thinking and 'critical practices' of academics across three disciplines, History, Philosophy, and Literary/Cultural studies in a university in Australia, whereas Philips and Bond, (2007) interviewed undergraduates students enrolled in a management course in New Zealand. Tsui, (2001) and Halx and Reybold, (2005) also conducted interview research to find out teachers and students' perceptions on critical thinking skills and critical thinking instructions in an American context. The present research employed semi-structured interview to illuminate the scenario of critical thinking development, instruction and practice in engineering FY in the UK context.

4.6.2 Administration of Interviews

The interviews were conducted between the researcher and two different groups of research participants 'face to face', in two different ways. The first set of interviews was conducted with student participants in three stages during a course of a year, while the module instructors were interviewed once. Student participants were given sufficient interval time between interviews for personal reflection on their development of critical thinking at the various stages of the FY moving on to a bachelor's degree. Thus, the Stage One interview was conducted from February to March 2015, the second stage, June to July 2015, and the third from February to April 2016. Prior to the actual interview an informal one to one meeting was arranged to brief participants on the nature of the interview; (i) that the interview would be a formal encounter with a purpose and not a conversation, Drever, (1995), (ii) it would be tape recorded and notes would be taken, (Rogers and Kalmanovitch, 2005). This specific purpose of the interview was made known so both the interviewer (researcher) and interviewee were aware of what was expected from the interview.

The interviews were conducted following an *Interview Guide (Student)*, (*Appendix H.1 on p 279*). Different interview questions were asked at the three different stages. The Stage One questions were to elicit background information about the students, their attitude about the EFY programme and their pre-existing knowledge of CTs. Stage Two questions were focused on students' experience using critical thinking skills in exam conditions, and Stage Three was about their overall perception about critical thinking in their FY programme, attitude towards learning and developing the CTs, the role of language, culture and previous learning experiences in developing the skills, and students' reflections on their learning experience in critical thinking in the FY and its contribution to their Year 1 undergraduate learning.

The instructors were interviewed with another specifically written interview guide (*Appendix H.2 on p 281*), designed so that the interview flows naturally. Therefore, attempts were made that any difficult questions, for example defining concepts were not asked at the beginning of the interview as this could confuse, or inhibit the interviewee to communicate what he or she intended to say freely, as suggested by Drever, (1995) and Opdenakker, (2006). Apart from that, the interview process took into consideration their convenience on time and place. As such, the researcher took sufficient time to plan the interview schedules and interview guides so that the interviews would produce high quality data. The interviews guides were not piloted, but the general idea of what to include in the questions was partly developed through casual conversations with students and instructors at computer labs, cafes and social gathering. The online academic public research groups' supplementary source was also used to construct the interview questions. All the interviews were transcribed using verbatim method as the research focused on the content and not on the linguistic features.

4.6.3 Document Analysis

The other main qualitative data source for the research was generated through content analysis of relevant course documents. In qualitative research technique, this is described as a flexible way of analysing and interpreting document data, Cavanagh, (1997); Hsieh, Hsiu-Fang and Shanon. (2005). The technique was used to analyse EFY module profiles and other general curricular for the discipline of engineering to address the research questions on faculty's perception of critical thinking skills and how it is reflected in EFY course documents. Content analysis was conducted using a thematic approach through a systematic classification process of coding and identifying themes and patterns and documents were analysed with the use of NVivo Pro 11. The modules used in the document analysis are shown in (*Table 4:4*).

Table 4:4 Summary of the Module Profiles used in Document Analysis

NOS.	**MODULE PROFILES (code and title)**	**UNIVERSITY**	**ID**
(i)	GENG 3894: Foundation Year Description for Engineering	X	EFY_X
(ii)	GENG 0016: English for Engineers and Scientists	X	EES_X
(iii)	Language Pathway A	X	PWA_X
(iv)	Language Pathway B	X	PWB_X
(v)	GENG 0004: Electricity and Electronics	X	EE_X
(vi)	GENG 0005: Engineering Principles	X	EP_X
(vii)	GENG 0003: Mechanical Science	X	MS_X
(viii)	GENG 0001: Mathematics A	X	MTA_X
(ix)	GENG 0002: Mathematics B	X	MTB_X
(x)	GENG 0014: Routes to Success	X	RTS_X
(xi)	GENG 0015: Coursework	X	CW_X
(xii)	CET 004: Electrical Technology	Y	ET_Y
(xiii)	CET 005: Introductory Engineering Mathematics	Y	IMT_Y
(xiv)	CET 007: Project	Y	PROJ_Y
(xv)	COM 001: Information Technology	Y	IT_Y
(xvi)	MAT 001: Mathematics	Y	MT_Y
(xvii)	MAT 002: Statistics	Y	STATS_Y
(xviii)	ENG 001: Study and Communication Skills	Y	SCS_Y

The analysis approach selected was used together with NVivo Pro 11 software to start the search for occurrences of words and phrases which reflect critical analysis or critical thinking skills. This provides basic insights into how words are used. However, to explore the conceptualisation of critical thinking skills underlying the documents, the designed *Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering* (DLC, PNE and CDIO) will be used as a point of reference to develop understanding of how CTs are interpreted in the discipline.

4.7 Interventions and Measurements: Risk Assessment

It was not anticipated that the data collection using semi-structured interviews posed any threats or risks to the research participants. As for the semi-structured interviews a digital recorder was used to record spoken data. Interviews were conducted in a conducive environment within the selected university ground mainly in a booked room in a library with close proximity to security facilities, therefore, this did not pose any physical threat to participants. For all types of data collection, anonymity and confidentiality were assured. Sensitive issues, for example, political, religious, and personal issues were avoided in the questions at all times.

4.8 Study Management: Ethical Considerations

Ethical issues were addressed by observing confidentiality and anonymity at all times as recommended by Shenton, (2004); Wiles, *et al.*, (2006) and Flick, (2009). Before conducting the research, the prospective participants were given as much information as might be needed for them to make an informed decision about participating in the research, (Denzin and Lincoln, 2008). Further, consent forms were given to get their official agreement to participate in the research. The confidentiality of the participants was observed: (i) by not sharing the information given by them openly to others, (ii) data collected were stored and coded and kept in a safe place, (iii) pseudonyms were used to protect participants' identities. It was agreed between the researcher and the participant that any information collected from them would be shown to them to confirm and to validate the findings.

4.9 Conclusion

The present study explored the phenomena with a longitudinal approach by employing two research instruments to answer the research questions.

Interviews and course document analysis were the main source of data for the research. The interview data was collected and analysed for content. A detailed analysis of students' interviews will be reported Chapter 5 (*on p 73*), followed by a report on the module instructor's interview Chapter 6 *(on p 151*), and finally the document analysis of EFY module profiles Chapter 7 (*on p 181*).

In sum, the methodology chapter has explained and discussed the research aims, research questions, and research design, the theoretical framework (perspectives) that underpins the study, the context of the study, research participants, research instruments used, and data collection procedures of the research. The research management and the ethical issue has been briefly explained.

Chapter 5 Findings: Student's Interview Report

5.1 Introduction

This report presents a sample analysis of part of the qualitative interview data which explored students' perceptions on Critical Thinking skills (CTs) for engineering and their development over a period of a year. The participants in the interviews were Engineering Foundation Year students from the cohort year 2014-15. The interview data comprises a series of semi-structured interviews conducted with engineering foundation year students representing three different groups based on their previous learning and cultural background.

5.2 Interview Participants

Students who participated in the interviews were Engineering Foundation Year (EFY) students from cohort 2014-15 academic year from University X. The participants took part in the interviews on a voluntary basis and formal consent was obtained through ethical approval.

In this research, a student with hearing impairment volunteered to participate which allowed representation of inclusion in sampling. The participants came from three groups; in the first group there were two students from non-western countries (International), in the second there were four from European countries, and another four students were English native speakers from UK and USA. The participants came from two different age groups, the first ranging from age 18 to 24 with a total of eight participants, and another two from age 25 to 33 plus. Besides that, both female and male participants were recruited, though only one female took part in all of the interviews.

Initially a total of thirteen students agreed to participate, however, two of the international participants withdrew after the first stage and another after the second interview, therefore, only ten took part in all three interviews. Background information of the student participants is shown in *Table 5:1* (*on p 74*).

Table 5:1 Background Information of the Interview Participants

Participant ID	Age	Education	Languages	Disability
SS01_M_I_Bahrain	19	International Baccalaureate (British curriculum)	English and Arabic	None
SS02_M_I_Libya	19	Private School (overseas)	Arabic + scored above 6.5 in IELTS	None
SS06_M_EU_Greece	21	Previously did Law in Greece and quit after 2 years to do Engineering Foundation Year	Greek + scored above 6.5 in IELTS + attended private English course	None
SS07_M_EU_Poland	19	Public funded school (overseas)	Polish + scored above 6.5 in IELTS + attended private English course	None
SS08_M_EU_Latvia	21	Public funded school (overseas)	Latvian + scored above 6.5 in IELTS	None
SS09_M_EU_Cyprus	27	Completed a Law degree in Cyprus University	Turkish (IELTS result not disclosed)	Yes (post-lingual deaf)
SS10_M_UK	19	UK state school	English	None
SS11_F_UK	19	UK private girls' school	English	None
SS12_M_UK	31	UK college qualification (no detail provided)	English	None
SS13_M_USA	33	Bachelor's degree in science from military university, USA	English	None

5.3 Data Collection and Interview Procedure

Timescale and interview procedure

The interviews were conducted at three different stages over the period of a year. The Stage One interview was conducted at the beginning of Semester Two (2014-15) Engineering Foundation Year (EFY), the Stage Two interview was at the end of EFY, and the Stage Three interview was at the beginning of Semester Two (2015-16) Year 1 of the undergraduate engineering programme.

Data collection and data preparation

The interview was fully conducted in English to avoid any miscommunication and misinterpretation of information during translation. All interviews were audio recorded, transcribed using verbatim transcription, coded and stored in accordance with research ethical guidelines.

5.4 Data Analysis

The research seeks to identify new emerging theories on critical thinking and engineering based on measured observation and recurring pattern in the data. Data analysis was conducted using combination of deductive and inductive coding. The research questions were used as a starting point to identify the main categories and themes to analyse the data. The coding system was further developed based on the recurring pattern of words and phrases which clustered into themes to identify the main categories. The data was then manually coded based on words and phrases or similar meanings.

5.5 Interview Research Questions

This report on Stage One interviews only includes analysis conducted on the ten participants who attended all three interview sessions over a period of a year. The interviews were conducted face-to-face, and lasted between 30minutes and 60 minutes. The Stage One interview was designed to contribute to answering the following research questions:

1) What are Engineering Foundation Year (EFY) students' perceptions and attitudes towards critical thinking skills at the beginning and at the end of the programme?
2) How do students learn and develop their critical thinking skills in the engineering foundation year programme?
    a) To what extent do students have the opportunity to practise critical thinking skills in the engineering foundation year programme?
    b) What types of critical thinking skills are students exposed to during the foundation year?
    c) To what extent does students' prior learning influence their ability to learn and apply the skills in their foundation engineering study?
4) Does a student's cultural background affect his/her ability to learn and apply critical thinking skills?

5) To what extent does language play a role for students in learning and applying critical thinking skills?

5.6 Stage One Interview

An interview guide was used to elicit information from the research participants using a semi-structured interview technique for the interviewer to stay focused on the topic and at the same time to allow participants to express freely their views based on the questions given. The interview guide for the Stage One interview is attached *(Appendix H.1 on p 279).*

5.6.1 Development of coding system

Based on the interview data of ten participants from the Stage One interview, the following main codes and subcategories were identified.

The following are the final main categories identified:

(i) Knowledge
(ii) Attitudes
(iii) Previous Learning
(iv) Language
(v) Practice
(vi) Culture
(vii) Independent Learning

The data analysis show differing perception on the knowledge and attitude toward critical thinking skills among all three groups. The differences in their perceptions were largely influenced by *Previous Learning* in general and the participants' interest in engineering and scientific subjects.

Practice has often been interconnected to engineering modules worksheets, lab reports, course assignments and group works. Similarly, *Knowledge* and *Attitudes* are noted to have some connection with a new emerging category, *Independent Learning*.

Language was treated as a main category. The data shows language in the perceptions of engineering students is not restricted to language as a communication tool, but is interpreted also as computer coding language and numerical language for Mathematics. It was also noted *Language* had a tendency to overlap with *Previous Learning,* for example participant's views on language were connected with types of schooling (whether public or private education received), attendance on private English courses and also participant's personality.

Culture is another category identified which has moved away from broader understanding of culture and society to academic *Culture*. This is proved to have some connection with *Previous Learning* which is largely connected to family influence and previous schooling. The analysis shows very minimal differences between groups based on the types of education received. Participants feel generally well prepared by their previous education and family experience for the new academic culture at the university, but two mature students were anxious and felt they were repeating some of the modules offered to them.

Overall the critical thinking skills pointed out by the participants already have close relationships with their interest in their favourite engineering modules. Otherwise, the analysis shows the emergence of a new sub-category *Independent learning* as an outcome of their individual learning experiences in the engineering programme, which has often interconnected with *Practice* as shared by the participants.

The research is an exploratory study seeking to find out new emerging theories in critical thinking skills for engineering. Therefore, the research did not aim to provide a definitive list of comprehensive definitions for critical thinking skills for academic and engineering context. However, the analysis gives a new insight into a range of definitions of critical thinking pointed out by the EFY participants.

5.6.2 Knowledge Category

Knowledge category for the Stage One interview concerns the participants' pre-existing knowledge of critical thinking skills. The analysis explores how participants define critical thinking skills based on their previous knowledge and their own understanding. The data shows almost all the participants were able to define critical thinking skills in one way or another, even at Stage One.

Knowledge of critical thinking is one of the main categories found in the analysis. *Problem solving* was the most frequently mentioned interpretation of critical thinking mentioned by the interviewees. Six from ten participants defined critical thinking skills as *problem solving* skills. However, this definition only came from participants from the European and English native group and neither member of the International group. This is followed by the interpretation *critical evaluation* offered by two participants one each from the International and European group. *Independent thinking*, *making clear judgement*, *productive way of thinking*, *conscious thinking*, *scientific thinking*, and *looking for mistakes*, were also mentioned, but appeared the least of these students' attempts as defining critical thinking.

Coding System for *Knowledge* Category

i. Problem solving
ii. Critical evaluation
iii. Making clear judgement
iv. Thinking independently
v. Scientific thinking
vi. Conscious thinking
vii. Productive thinking
viii. Analysing and synthesising
ix. Self-correcting
x. Objective evaluation on environment and information
xi. Identifying mistakes

Problem Solving

When asked to define critical thinking, participants mention *problem solving* quite frequently in various contexts with reference to their academic tasks in their engineering foundation programme and also to real life situations. Their initial perceptions about *problem solving* largely make reference to mathematics and physics, i.e., solving mathematics numerical problems and physics theoretical problems. Participants also mentioned the importance of applying a logical process to solve a problem and explained that *problem solving* skills require a good understanding of subject matter, knowledge of word play and some creativity. One of the participants believes that at times this does not need coaching or to be taught, but comes naturally on how a person thinks.

Examples:

i. *Critical thinking…about things that you have to deal with, the problem that you encounter and how to solve them, and not to solve them in the way to get the answer correct, but to know why this answer is correct in the term of every part of the answer is it clear or concise.* *(SS07_M_EU_Poland)*

ii. *Critical thinking as I see is as problem solving. So, the great thing about science in general is just the application of logical process, that's process of logic given to us by philosophy. So, I see critical*

thinking is that, you just apply logic, critical process to <u>solve a problem</u>, as much <u>as identifying the problem</u> as much as <u>solving them.</u>
(SS10_M_UK)

iii. *I think it comes along with <u>problem solving</u>, being able to visualise problem and being able to see what is actually been given and work out central solution.*
(SS12_M_UK)

It was noted that one of the participants (SS07_M_EU_Poland) also used some specific words for example, *clear* and *concise*. These may reflect some awareness of *clarity* and *precision* which are some of the criteria of critical thinking skills.

Two participants' (SS11_F_UK) and (SS08_M_EU_Latvia) response at this initial stage of the interview were linking *problem solving* skills with reading and text comprehension which involve language skills in order to complete a task.

Examples:

i. *I'm not sure really, for me it's all about <u>analysing the question</u> and <u>completing a task</u> successfully.*
(SS11_F_UK)

ii. *<u>Problem solving</u> being able to <u>visualise a problem</u> and be able to see what is actually been given and <u>work out central solution</u> and sort of to <u>read a bit of text</u> and being able to extract the information you need out of it and understand what it is and then <u>work out what you got to work out.</u>*
(SS12_M_UK)

Whereas, others tended to focus more on mathematical solutions and using scientific method as *problem solving* skills.

Examples:

i. *Can be something like when you're looking at a <u>problem which you want to solve</u> being able to <u>indicate the factors</u> are, indicating the things on which this problem depends and knowing how to deal with it in a feasible manner, there's some interpretation to that, it depends to the context.*
(SS08_M_EU_Latvia)

ii. *The way I would see it would be that, you take <u>principles of science, scientific concepts, laws</u> and stuff, you take <u>Maths</u> which is essentially a language, you apply them both, use those as your tools to <u>solve problem</u> by critical thinking.*
(SS10_M-UK)

When participants interpreted critical thinking skills as *problem solving* skills, they also express their appreciation to scientific methods and engineering concepts and their contribution to critical thinking skills.

Critical Evaluation

Critical thinking skills are also perceived by participants as *critically evaluating* ideas or opinion based on merits and supporting evidence. Both the participant (SS02_M_Libya) and (SS08_M_Latvia) stressed the importance of evidence and the reliability of the source of the evidence in critically evaluating something.

Examples:

i. *Criticising an idea, if something seems to be wrong and you have evidence to prove that so you criticise it to some extent I mean politely, and if the other person being opposed have shown you evidence you have to change your mind, that's what I think.*
(SS02_M_I_Libya)

ii. *Critical skills can be defined as being critically evaluating somebody's opinion based on how much merit that person has and, so for example let's say he has an essay on certain topic and you evaluate what kind of references he has, and if his arguments make sense, and if he has data for that, something like that.*
(SS08_M_EU_Latvia)

It was also apparent that the participants also have some good basic knowledge on what is an acceptable approach in applying critical thinking skills, for example participant (SS02_M_Libya), expressed that when *critically evaluating* someone's idea it needs to be conducted, *politely*, which is respecting and being fair-minded in recognising different perspectives and views. Furthermore, the participant mentioned that in *critically evaluating* an idea it was important to recognise the evidence provided and if it supports the truth, then, the judgement can be suspended for a fair evaluation.

However, when talking about the concept of critically analysing an argument as a type of critical thinking skill in this context, participants claimed that this skill is applicable in general contexts and not necessarily in engineering or science but in real life situations.

Making clear judgements

The ability to *make a clear judgment* in order to produce a clear decision was treated as being able to think critically by one participant (SS07_M_Poland). However, the participant admitted that he was not very sure about this concept. He had to google the meaning of critical thinking skills before the interview, he claims that he does not want to discuss something that he does not really know.

Example:

i. *Wild guess. It's like being able to make like clear judgement about decision, about the problems, about things that you have to deal with, the problem that you encounter.*

(SS07_M_EU_Poland)

This participant, (SS07_M_Poland), also connects *making clear judgement* to making sound decision. *Making clear judgement* is focused on making a decision in a transparent manner to avoid any subjectivity. Even though he was not certain about his understanding of this concept, he stressed the importance of clear thinking in help to make sound decisions.

Thinking Independently

Thinking independently is another way of understanding critical thinking skills and this was connected to culture according to some participants. It was explained that if one has not been encouraged in his culture to express his view than it would be challenging for the person to apply the skill of independent thinking.

Example:

i. *To be able to think independently and not just remember what you're told and regurgitate that. To be able to question what you're learning and seeing. It's hard and it comes with maturity, experience … I think the hardest part of that is that if you're not taught to question your elders or the authority you're not going to do it unless you're allowed to practise that out.*
(SS13_M_USA)

In this context the concept of culture is seen as to conflict with the idea of critical thinking skills. This shows the participant's perception towards critical thinking is for someone to think and react without other's influence. This, therefore, comes with the freedom to practise which at times could be inhibited by cultural norms.

The participant (SS13_M_USA) also stressed that to be able to *think independently* a person needs some maturity and experience in the field. The participant is a thirty three year old mature student and had experience working in the US Navy before joining the engineering FY programme in the UK. Therefore, his definition of critical thinking skills could be influenced by his own personal experience in handling difficult situations in the navy as part of a team and solving problems.

Scientific thinking

The participants who were in-favour of expressing critical thinking skills as *scientific thinking* were noted to have a deep appreciation for science and scientific methods of thinking about something. Their passion for science was reflected repeatedly throughout the interview on several occasions, for example critical thinking skills as *scientific thinking* was also useful in their personal lives beyond engineering context.

Examples:

i. *I came to get a degree in Physics and Science, because I want to get acquainted with the scientific way of thinking first of all. I like the knowledge, but, first of all I also like the way science think, that's you have to raise the truth, that you always judge and question everything, that's what critical thinking is for me. Like question everything, knowing why you're doing anything that you do, and not just like solving a formula, or like I have to do well in exams, no!*
(SS06_M_EU_Greece)

ii. *I have developed appreciation for scientific method because I actually because, most people who don't study engineering or sciences, they see sciences as something that you can easily distinguish from your everyday life. While all the technology that we're using, even the basic, everything is based on our knowledge on basic mechanics, Newtonian physics or beyond, it's all based on research and critical thinking.*
(SS08_M_EU_Latvia)

These participants claimed that science and engineering by definition involve critical thinking skills and believe that science is important to seek the truth and this could be achieved though critical thinking skills. Participant (SS06_M_EU_Greece) also believed that in the process of seeking the truth through critical thinking is central to learning, and has implications for personal identity.

Example:

i. *Critical thinking is like pushing me to find the truth and define the better idea of the time, so just instead of having an idea something that give me identity and not changing it critical thinking forces me to change my identity every time it collides with the truth.*
(SS06_M_EU_Greece)

Conscious Thinking

Critical thinking is also identified as *conscious thinking* by the same participant in which this could relate to taking responsibility for your own thinking.

Example:

i. *I would say critical thinking for me is conscious thinking, in terms of that critical thinking is about knowing the reason behind everything, it's about not learning something, but, learning to think about something.*
(SS06_M_EU_Greece)

Productive Thinking

Critical skills are also perceived by SS06_M_EU_Greece as generally *productive thinking* with relation to social and life skills as being a proper way of thinking about something. This participant pointed out the importance of leading a successful life and critical thinking skills could help him to achieve this.

Example:

i. *I want to do well in my life, and in order to do well in my life, is to learn to find a way to of proper thinking, of a very productive way of thinking in many fields, not only in subjects, and usually critical thinking in many subjects may give me, I may use this to apply later in my life, like in the foundation year, studying abroad, living abroad all combined.*
(SS06_M_EU_Greece)

Analysing and Synthesising

Critical thinking skills are also identified *as analysing and synthesising* skills by another participant. He explained it was important for him to understand a problem in-depth by analysing each component separately in detail and then putting them together to identify the contributing factors in order to solve the problem given.

Example:

i. *I'd say, well, you get a wide, I mean a good idea of the problem you're facing and then, break it down into parts and then you look at each part individually and you go into more depth, and that way for me that's critical thinking because you're going into more depth allowing you to understand the problem a bit more.*
(SS01_M_I_Bahrain)

Self-correcting

Self-correcting is another code identified in the analysis of the comments of the most science-oriented of the participants. These participants mentioned that they need to self-correct themselves first by self-questioning, and then questioning their surroundings, evaluate the information received through scientific method and decide for themselves what to accept and reject based on merits, and that this is a continuous process.

Examples:

i. *Most people just evaluate everything from their emotional state and how they perceive it from their own perspective, and the scientific method doesn't rely on that. It's always self-correcting, it always forces you… it's very difficult to phrase that. By using scientific method, the person is evaluating all the available information, and then trying to disprove it in every possible way to see how much merit it has, and keeping that.*
(SS08_M_EU_Latvia)

ii. *Critical thinking is the basis of cosmos theory, so, it's very important about socialising, about studying, about managing your time, managing yourself, because, in order to be well socialised first I have to know what is going on with me. Why I have to force my character based on some cosmos theory. If I don't have critical thinking like to try to know why I think the way I think then I'm just like a robot that was programmed by the society that told me and think this way. Then, I just replay the same pattern all the time unless I apply critical thinking and try to decide by myself what are my theories, what my ideas are, how I see other people, how I see myself.*
(SS06_M_EU_Greece)

However, participant (SS08_M_EU_Latvia) focused *self-correcting* more on scientific methods, whereas participant (SS06_M_EU_Greece), saw this as an element of identity and applicable to all aspects of life.

Objective evaluation on environment and information

For one participant, critical thinking skills were also perceived as, *objective evaluation on surroundings and environment and on environment*. In this context any evaluation needs to be conducted in an objective way that will eliminate doubts and avoid scepticism.

Example:

i. *I* *Now before we end, coming back to your definition of critical skills, how would you define it simply now?*

SS08 Objectively evaluating, ah (_) objective evaluation of surroundings and environment. I suppose objective evaluation of information.

(SS08_M_EU_Latvia)

Identifying mistakes

Identifying mistakes is also viewed as intrinsic to critical thinking skills based on the data analysis. For one participant, identifying mistakes was important because it would help to find out what to do next. This could be how to fix the mistake or solve the problem by identifying what contributed to the mistake.

Example:

i. *Critical thinking for me is to find out the next stage of something or to find out what is the mistake, what is the different things in a theory, to find out the mistake in a theory.*
(SS09_M_EU_Cyprus)

This participant (SS09_M_EU_Cyprus) was interested in identifying similarities and differences in patterns as any mismatch could result in not achieving the desired outcome.

The initial analysis of data obtained from the Stage One interview on knowledge category to find out about the pre-existing knowledge on critical thinking skills among FY students have produced a whole range of ideas which could be categorised as critical thinking skills in general and academic context. The analysis on *Knowledge* category shows that though participants were uncertain of their definition of critical thinking skills, it was apparent that they all have some pre-existing ideas on critical thinking skills.

Participants' pre-existing knowledge was apparent when they defined critical thinking based on their own understanding. Some participants were able to use more than one expression to define the concept of critical thinking skills. Participant (SS06_M_EU_Greece) was able to produce four different expressions to define his understanding on critical thinking skills, for example, *scientific thinking, conscious thinking, proper thinking*, and *productive thinking*. Similarly, another participant (SS08_M_EU_Latvia) defined critical thinking skills as *problem solving, critical evaluation, objective evaluation of environment and information*, and *self-correcting*. This is followed by another participant (SS07_M_EU_Poland), who defined *critical thinking* skills as *clear thinking*, and *problem solving*. The rest of the participants gave only a single definition of critical thinking skills.

Clearly, the research is interested in finding out if the students' understanding of critical thinking skills as it stands now will change, remain or gain more knowledge after having completed their FY programme and moved on to their Undergraduate (UG) programme which is expected will be known in Stage Three data analysis.

5.6.3 Attitudes Category

The analysis of participants' attitude towards critical thinking skills and their development through foundation engineering year was conducted by looking at participants' views and how they feel about being engineering foundation year students. Participants' views on the importance of critical thinking skills for engineering study were also captured using this main category.

Coding System for *Attitudes* Category

(i) Sense of importance
(ii) Sense of uncertainty
(iii) Sense of satisfaction
(iv) Sense of confidence
(v) Sense of frustration

Sense of Importance

Participants' attitude towards critical thinking skills and FY programme was coded when participants shared their experience as engineering foundation year students, and whether they thought that critical thinking skills were important at the foundation level. A majority of the responses show that they believe critical thinking skills are important at the foundation level and that they have positive attitudes towards the skills.

Examples:

i. *It's extremely important, it's the base of good living, it's a cosmos theory for me, that's why I think it's difficult for me to say if a foundation year is giving me this critical thinking, because critical thinking is a result of [maximum?] parameters, that it starts from a young age, so if someone, doesn't have acquired critical thinking since his young age it's impossible for the university to give him critical thinking.*
(SS09_M_EU_Greece)

ii. *This is like <u>not just foundation year</u>, the way I see <u>engineering in general</u> … The world produces a lot of problems but you can <u>use critical thinking to identify the solutions, engineering just gives you the tools, critical thinking is the mind-set that you have to have to be an engineer.</u>*
(SS10_M_UK)

iii. *I would say obviously they're <u>very important</u> for us, very important because foundation year students, we haven't sort of you would say, been introduce to our actual degree. You know next year is when we actually start our proper degree, so <u>critical thinking will obviously help us to understand how we're meant to approach and solve problems in which we'll face next year</u>.*
(SS01_M_I_Bharain)

However, there was one participant who only partially agreed that it is important and another who viewed it as not very important at foundation level.

Examples:

i. *They are <u>quite important</u> once you actually try to solve old but more advanced problems, I wouldn't say that you cannot pass without minimal use of critical thinking skills… therefore you're not going to use that much of a critical skills but once you start to do a little bit more non-standard tests… they are <u>partially useful</u>.*
(SS08_EU_M_Latvia)

ii. *I think it is <u>not too important</u>, but it will be important when I'm in the main department, engineering department, because I have to think about everything…so, I think it will be <u>beneficial next year</u> not now…at this moment we have taught theoretical of something, they just <u>try to give the basic</u>, so we are expected to find the mistakes.*
(SS09_M_EU_Cyprus)

Sense of Uncertainty

There was a recurring pattern in the ways that participants expressed their understanding on critical thinking skills. Almost half of the responses show participants were uncertain in conceptualising critical thinking skills mainly at the beginning of the interview. They were ready to admit that either they are not familiar with the term, not sure if they understood the meaning well, or if they have sufficient information about critical thinking skills for them to talk about them. Participants' sense of uncertainties were coded through their direct verbal responses, the use of repeated questions and behaviour.

The example below shows the uncertainties expressed by one participant in the form of repeated questions to prepare himself before attempting to answer the question in defining what critical thinking skills are for him. The participant's uncertainties could also be observed by his behaviour when he started laughing when the question of critical thinking skills was raised.

Example:

i. I *So, what are critical thinking skills for you?*

SS01 *[laughs] Like, <u>how do you mean</u>?*

I *So, if you were to explain, okay this is what entails critical thinking skill, so how would you define it, personally as a student now*

SS01 *Umm <u>how would I</u>?*

I *You don't have to like sort of refer to a scholarly view*

SS01 *Yeah*

I *As a student?*

SS01 *<u>How I see</u>?*

I *Yeah*

SS01 *So, <u>what's expected of me</u> when I'm asked to think critically*

(SS01_M_I_Bahrain)

Other participants also expressed uncertainties immediately when they were asked to explain what critical thinking skills are for engineering study.

Examples:

i. *I <u>don't have good idea</u> about that, I <u>don't know</u>, it encourages you may be to criticise certain ideas.*
(SS02_M_I_Libya)

ii. *I'm <u>not sure</u> really, for me it's all about analysing the question and completing a task successful.*
(SS11_F_UK)

The sense of uncertainties in defining critical thinking skills appeared almost in all the interviews. However, this was only observed at the beginning of the interview and gradually disappeared when the participants were asked to provide examples based on their own experiences on how they applied such skills in academic or social contexts.

Sense of Satisfaction

Sense of satisfaction is coded when participants talked about their learning experience as students of engineering foundation year. A majority of the responses indicated participants were satisfied with how the programme is designed and supportive in guiding them to cope with the programme and prepare them for their destination course the following year.

Examples:

i. *I enjoy it very much. Definitely I think. It offers me so many things, I benefitted in many ways, I think I benefitted very much in whole of foundation … the way I think, the way I manage myself, and the ways I manage many things of my life. And, I'm thoroughly happy about how I'm progressing. I am happy with the way FY is organised too.*
(SS06_M_EU_Greece)

ii. *Enjoyable, it's very different from school as to be expected.*
(SS10_M_UK)

The analysis shows that participants were not only satisfied with FY programme, but also the extra facilities provided by the university, for example language support courses.

Example:

i. *It's for me opportunity for me to practise my English, and here this university gives me the opportunity to practise because we have, for example, we have English classes, English for Academic classes, I took part in those classes. So, I'm trying to take as much from the foundation year, this year as I much as I can.*
(SS07_M_EU_Poland)

Sense of confidence

Sense of confidence was expressed by just two European participants. Their confidence is based on their personality, their achievement in their previous education, and their proficiency in English language.

Examples:

i. *I find myself quite confident, experience that I gained in my high school. Because I learnt a lot from my high school, my high school is really good, it gave me this preparation for further education… I managed start speaking English fluently, which is for me is a great achievement, I think.*
(SS07_M_EU_Poland)

ii. *So far, it seems it's going fine for me. I might have put an extra effort in this, but at the same time I don't find any strong sort of incentive for me to get the highest possible result because in the end it won't matter that much in contrast with what I'll get next year because next year I will actually focus on the specific types of engineering and that will matter more on my results … at the moment I don't feel that I'm failing at all.*
(SS08_M_EU_Latvia)

Sense of Frustration

The interview analysis also identified *Sense of frustration* as expressed by some participants. From all of ten interviews analysed it was apparent that four participants shared their dissatisfaction as engineering foundation year students. Their dissatisfaction varied depending on their individual circumstances, and referred to the programme design, restricted language support classes and insufficient disability academic facilities.
The participants who expressed frustration on the programme design were mature students aged thirty one (SS12_M_UK) and thirty three (SS13_M_USA), who had obtained a college and a bachelor degree qualifications prior to joining the FY programme. The main frustration mentioned by SS13_M_USA was that there was repetition in some of the subject content which he found to be at a very basic level which was not beneficial for him though it may be for those without so much experience in the subjects. SS12_M_UK, thought that he would have benefitted from more advance preparation.
Examples:

i. *I found it's been an exercise in patience. I feel that most of the time that I've spent is either waiting for lecture or waiting for an assignment to be due or waiting for revision time, waiting for the exams. I know that sounds I'm don't make use enough of my time but I really feel that sitting in workshops and support sessions are waste of my time and I can honestly feel myself becoming demoralised, demotivated by that time passing*
(SS13_M_USA)

ii. *It has been quite a tough year, I think. There's a lot of contents to learn and if you've haven't done much of it beforehand, there's missing gaps or information that you need to know before coming onto this course just to keep up with the material. And, one of the things that would have benefitted people was a list of things that you needed to know like rearranging the equations and certain formulas, stuff like that before we actually start the course. One of the lectures I think pretty much a waste … it's like wasting a lecture at the start of the year. I'd rather not sit in that lecture, and do over the summer and make sure that I know it … and would have a lecture to cover another harder content.*
(SS12_M_UK)

Sense of frustration was also coded by one participant (SS02_M_Libya) who would have preferred to join the language support classes. He was unable to join the class, because English Language support class was only offered to students who did not meet the university English Language requirement, and this was controlled by programme personal tutor, who decides who could attend the class. This participant would have preferred it if they were given the choice to choose rather than it be decided for them.

Example:

(i) *The course is quite intensive… and, so many new things, I don't know, there isn't enough time to study every module on this course. And I think, for me as my English is not first language I would rather I took English Pathway for me… they said I had scored IELTS score enough … I wish I didn't do well because I have like three modules Physics and one Maths, but the English Pathway students have less pressure, and they only have English. They don't have EP, they take away EP or EE or something like that, so less pressure.*
(SS02_M_I_Libya)

The *sense of frustration* was also expressed by SS09_M_EU_Cyprus, due to insufficient academic support for disabled students. This participant with a hearing disability found the programme and university do not provide sufficient support for a conducive learning environment.

Example:

i. *At this moment foundation year I think sometimes it is easy, sometimes it is difficult because of my hearing difficulty, some anxiety issues. So, generally I find myself alone in the education because everyone learn everything in the classroom, however, I don't have such an opportunity because I can't hear in the class room, so, I have to study in my own place … because most of the people can hear at the lectures at that moment, however I have to struggle much more than them…so sometimes the problem build up that increase my anxiety.*
(SS09_M_EU_Cyprus)

The same dissatisfaction was also present when the participant was asked if he practiced his critical skills using other support sessions provided within the FY programme.

Example:

SS09I can't benefit from them because I have communication disability with them, so I completed most of my lab sessions alone, so I have my work signed. So, about critical thinking I couldn't benefit from them.

I The PGTA if they use sign language do you think you would have benefitted?

SS09 Sign language? I'm not sign language user, I know sign language Level one, but my main communication is based on writing or visual clues

I Alright

SS09 Because I'm a post-lingual deaf, so I'm not adult deaf people either or hearing person, I'm in between

I So, writing and some pictures will help you?

SS09 Yeah, at the moment I'm looking at your lips. Lips reading, that is important for me.

(SS09_M_EU_Cyprus)

On the whole participants' dissatisfaction largely came from mature students, age range from 25 – 32. Three of the four students who expressed dissatisfaction had obtained experience in studying in college and universities. Therefore, they seemed to know what their academic needs are, and how the university could support them to achieve their academic satisfaction.

5.6.4 Previous Learning Category

Analysis of *Previous Learning* category showed the influence of previous education on participants' confidence level and their ability to use the target language fluently. This category also reflected the participants' experience in critical thinking in their previous education and family.

Coding system for your *Previous Learning* Category

(i) Types of education
(ii) Critical thinking experience in school
(iii) Critical thinking experience with family

Types of Education

Types of education refer to types of schooling or previous academic qualification. The examples identified show that the types of school or academic qualification obtained prior to joining FY programme has some influence in the participants' *confidence* level and their attitudes to critical thinking. It was noticeable that the participants who were non-native speakers of English were able to express their views with clarity and confidence without hesitations and wrong word choice.

Examples:

i. *When I was in Bahrain I went to British school, and then when we shifted to Dubai I went to an international school and there did the IB programme, International Baccalaureate a diploma programme ... it's a private school…it had the British curriculum like they did the A Levels.*
SS01_M_I_Bahrain)

ii. *I find myself quite confident, experience that I gained in my high school because I learnt a lot from my high school, my high school is really good, it gave me this preparation for further education.*
(SS09_M_EU_Poland)

Critical Thinking Experience in School

Critical thinking experience is mentioned by participants when sharing their school experience and referring to learning critical thinking skills. From ten participants interviewed one shared his experience of a critical thinking course in his previous school, the rest claimed either that they learnt critical thinking skills indirectly or they did not learn them in school.

The participant who had studied critical thinking skills in school claimed that he did not learn the skills extensively but limited to exam purposes, and did not fully understand the concept.

Examples:

i. *I actually studied critical thinking as an 'AS Level' course, I didn't do the full 'AS Level', it was just my school, they required us to do GCSE just the 'AS' part of it, or something like that. I didn't do well at all (laughs)…it's sort of a very vague, trying to teach vague concepts and trying to apply to, you know there were sorts of, a lot of word play like that sort of stuff. I think it might be have been useful for those who went on to do law, everyone else is pretty useless.*
(SS10_M_UK)

It was also identified that participants who recalled their experience learning critical thinking skills indirectly in their previous education related their experience with specific subject skills.

Examples:

i. *It was sort of implemented in all of the subjects we took in high school there wasn't such okay this is critical thinking and this how you meant to carried it out. It was just implemented in the subjects we took. So, I guess we're doing without us knowing that we're doing it. We knew that but we didn't know that it was critical thinking. Well, I took economics at higher level in*

high school as part of my IB programme and that involved lot of critical thinking because you have to take into account various factors and how they affect the problem you're trying to solve. So, that's how you have to take a problem like I said, break it up analyse it and then synthesise it.
(SS01_M_I_Bahrain)

ii. *We didn't have separate subject on that, we probably have some problem-solving tasks integrated in on the subjects, but not in many of them, maybe a few of them. Let's say, yes, maths had some of those, because I also participated in lots of maths competitions therefore, you had to some of those tasks were more advanced and they were, they required a little more of abstract thinking because a lot of this mathematical challenges did not involve numbers they were just involved like understanding of mathematical concepts trying to apply in a new way.*
(SS08_M_EU_Latvia)

iii. *I don't think I learned critical thinking skills explicitly, it was not taught explicitly. I think it was pretty much incorporated, but I think in my GCSE in History and English there's a bit of practice on critical thinking skills. But, once I moved to 'A' level it was more focused on the content on science subjects.*
(SS11_F_UK)

One participant considered that he encountered critical thinking assessment.

Example:

i. *I'm not sure I had much in my education system, although in high school. Like in high school, we had like module it was not about critical thinking, it was about language. So, we had to write composition in the final exams, and in this composition we had to apply critical thinking.*
(SS06_M_EU_Greece)

Critical Thinking Experience with Family

The analysis of the interview data also showed that participants experience with critical thinking skills in their previous learning did not only happen in their school, but at home with their family.

Examples:

i. *I'm very happy because I had the chance to learn critical thinking, but I think it started before school and it continued out of school by my family, my parents, the way they brought me up.*
(SS06_M_EU_Greece)

ii. *I haven't been specifically told that about critical thinking, just it suddenly comes up, I don't know some questions related to critical thinking in Physics and Maths in my high school, not exams but in the content of the materials itself, you find questions that there isn't a specific ways to solve them. It's, just how you approach it depends on you, it isn't right or wrong, if the answer is right then it's right. How you look at it, some questions you know. This in terms of like academic life, but in daily life I've been encouraged by my father, but in school I've never been encouraged by the teachers or something like that.*
(SS02_M_I_Libya)

5.6.5 Language Category

The analysis shows that perception on *language* is not just restricted to linguistics traditional views of language as either written or spoken, but could have different meaning based on context. In engineering language participants referred to mathematics as numerical language, and computer codes. Otherwise, all references to communication skills and English language were coded as *Language* categories.

Coding System for *Language* Category

i. Mathematics as Numerical Language
ii. Computer codes
iii. English Language

Mathematics as Numerical Language

In the analysis though, mathematics was noted to have a significant meaning in understanding the concept of *language* as used in engineering by a single participant.

Example:

i. *You take principles of science, scientific concepts, laws and stuff, you take Maths which is essentially a language, you apply them both, use those as your tools to solve problem by critical thinking.*
(SS10_M_UK)

Computer codes

In the engineering context it was apparent that participants tend to refer to computer codes as a type of language. The ability in computer skills is about proficiency in computer language.

Examples:

i. *I did learn programming. I learnt I think Pascal, but they did not teach programming to me at all. So, I had to learn programming again, I had to make a fresh start when I was learning python and now, as much I had read python it's probably one of the easiest types of languages for beginner.*
(SS08_M_EU_Latvia)

ii. *You have to know the system of coding, it's language it's Python. I don't think there's critical thinking about coding, it's just thinking but not critical thinking, I guess.*
(SS02_M_I_Libya)

The participant (SS10_M_UK) who perceived 'maths' as language also expresses a similar perception on *computer codes* as language.

Example:

i. *I think spoken is a very small example of that but it's a very important one that we take it for granted, but in engineering the language is Maths and also codes. So, what you really need to learn is how to be fluent in Maths and how to be fluent in codes. If you can do those, there's no strict applications, they work for anything, that's the beauty of language.*
(SS10_M_UK)

English Language

English language was coded in three different contexts; descriptions of previous learning, English classes and English language learning experience.

Examples:

i. *I started studying English since primary school since the age of ten, I think. I even going to get certificate for proficiency, but I didn't because I decided to come to England to study… I had private English class as well, because in school they teach us not so well, very low.*
(SS06_M_EU_Greece)

ii. *I had previous education in English as well in private English class. In case of my high school quite the same, English mostly I had to learn by my own.*
(SS07_M_EU_Poland)

Two of the ten participants interviewed discussed the issue of English as a second language, as it affected student experience in the engineering foundation year. The non-native speaker (SS02_M_I_Libya) shared his view in the context of himself. Whereas, a native speaker

(SS13_M_USA) shared his observation on one of his lab sessions run by the Post-graduate Teaching Assistance (PGTA) to support FY students in their laboratory work.

Examples:

i. *So many new things, I don't know, there isn't enough time to study every module on this course, and I think, for me as my English is not first language.*
(SS02_M_I_Libya)

ii. *It will help a lot with a lots of training so that they [PGTAs] can explain themselves properly and they know the whole content of the course and know what we're supposed to do. It feels like they just came out of their class which is 3 or 4 years removed from us, or they've never been in our situation at all and they have no, they are not teachers but they try to, and then it ends up being bad. You know, there this one guy who didn't speak English very well and he wasn't very social and I was very offended by the way one of the PGTA's was treating him. It was just kind of like it wasn't good, he was just not cool, the insensitive, the PGTA treated him very poorly.*
(SS13_M_USA)

One of the ten participants interviewed showed particular enthusiasm and motivation for learning English language.

Examples:

i. *I do everything I can to practise in English, so, whenever I have opportunity to go and speak to people, even it's like a casual conversation in halls, in the university halls when I'm speaking with friends like casual things … it's opportunity for me to practise my English, and here this university gives me the opportunity to practise because we have for example we have English classes, English for Academic classes, I took part in those classes.*
(SS07_M_EU_Poland)

ii. *I managed start speaking English fluently, which is for me is a great achievement, I think, because this is the purpose I come here to study in English … despite, the knowledge that I have to learn, despite the engineering programme, my only purpose is to start speaking fluently.*
(SS07_M_EU_Poland)

5.6.6 Practice Category

Practice here refers to practice of critical thinking skills within the EFY programme. Participants mentioned repeatedly their opportunities to practice the skills with reference to specific engineering subjects, i.e., Mechanical Science (MS), Routes to Success (RTS) and Electronics and Electricity (EE) modules. Worksheets were mentioned by participants in connection with *practice* meaning individual worksheets on critical thinking skills which they uploaded from *Blackboard*, the Virtual Learning Environment (VLE).

Coding system for *Practice* category

(i) Semester
(ii) Modules
(iii) Workshops
(iv) Lab work
(v) Support sessions
(vi) Worksheets
(vii) Individual assignment
(viii) Group work

Semester

The analysis shows participants overall find the FY programme did provide them opportunities to apply critical thinking skills for academic use on engineering related critical skills. From the ten participants interviewed, four of them believed that these opportunities increased in Semester Two for the reason they had enough content knowledge to learn to apply the skills to solve basic engineering problems.

Examples:

i. *I<u>n semester two</u> I did for example, more reading into our topics which in sort of what <u>helped me solve the problems in better ways</u>. Whereas, in semester one, I would skim and then try, <u>attempt the problems</u> and then I find them very difficult.*
(SS01_M_I_Bharain)

ii. *I would say <u>second semester</u>. Yes, because in the first semester they introduce everything to us like a start. And then, from <u>second semester we directly started all things very deeply let say of all the details.</u>*
(SS07_M_EU_Poland)

However, three participants found the first semester offered them more opportunities to learn and apply critical thinking skills.

Examples:

i. *I think in <u>semester one because we had more time to practise the skills</u>. I think all of us pretty much at the same level, but in semester two I find it to be too cramped focuses more of what we need to know, on the content and exams.*
(SS11_F_UK)

ii. *<u>More opportunities in the first part of the year</u> just that <u>not much pressure on our time</u> yet. We had <u>more time to explore into things</u> and there's not too much work to do … easier topics, you had the time to actually get through stuff that for me I had bits which I had to learn in this course, that I didn't know from college or school.*
(SS12_M_UK)

Others found that both the semesters gave them opportunities to learn and apply critical skills.

Examples:

i. *<u>Both semesters</u> because <u>they have different parameters</u>. For example, in the beginning the whole process of being introduced in the new way of life in the university atmosphere, it needs critical thinking. It makes me, it promotes my critical thinking. It requires it. Like the way I will meet people, the way I will manage my schedule, my time… the <u>first semester I had this course work assignment</u>, they are promoting critical thinking on their own. For example, the <u>reflection portfolio</u> … I think both because we have course works and assignments like this in <u>second semester</u>, too.*
(SS06_M_EU_Greece)

ii. *I would suggest both semesters were same in terms of critical thinking.*
(SS10_M_UK)

Modules

Based on the interview data analysis participants find some modules in the FY programme were better than others in providing more opportunities to practise their critical thinking skills. The modules with the most practical skills mentioned by the participants by rank were *Routes to Success, Mechanical Science, Electricity and Electronics, Maths* and *Engineering Principles*.

Examples:

i. *I think first of all the <u>Routes to Success</u> module which by definition is critical thinking, then I think all of them promote critical thinking…the reflection portfolio, that's in my opinion was excited and like I wasn't expecting university has, especially university degree in science in engineering which has something completely irrelevant with the studies themselves, but*

something that is basis for everything else, like I was surprised because I found I'm reflecting on myself and thinking about my motivation and all these stuff, which is extremely important.
(SS06_M_EU_Greece)

ii. *I would say MS and EE. The worksheets, the questions are not direct like maths which is about differentiate between two formulas. MS and EE worksheets allow me to think around the question more for the question, the situations are provided. And also, for MS and EE we have opportunity to have in-class practice. We're given a situation where we'll try to solve the problem by ourselves and we discuss the answers.*
(SS11_F_UK)

iii. *I would say Electricity and Electronics, again it was not the direct way because the lecturer didn't learn directly. He didn't teach us critical thinking directly but he was giving the lectures in a way that you really could learn how to think about his subject. How to clearly understand the concept of Electronics, so yeah, I was able to understand fully the topics during the lectures. And it was kind of critical thinking relevant to Electronics.*
(SS07_M_EU_Poland)

Workshops, laboratory works and support sessions

The interview data shows most of the participants benefitted from the extra support incorporated within the FY programme; *workshops*, and *lab work* and *support sessions*. Participants find this extra support quite helpful in their academic work and also to practice academic skills like critical thinking skills.

Examples:

i. *In class we were given a brief understanding of it and then when the worksheet came out of any topics of what we're learning … and then when the work sheets came out, we attempted the worksheets that's where we found that you have to use, and the workshops helped a lot because there were some questions just, we found them difficult and then when we went to workshops. We saw how the professors solved it and then we're okay it's not just a one step process you have to do various things and that helped a lot because we understood that you won't find the answer immediately. You have to do, you have to play around with the formulas first.*
(SS01_M_I_Bahrain)

ii. *In labs because you have to define the possible reasons for errors and you have to write your own reports, your own methods, how did you do, what's the amount, for example, water that you put in a container, something like that. The experience itself, the lab experiment but other things are mostly theoretical things most being formulas.*
(SS02_M_I_Libya)

One participant (SS07_M_EU_Poland) did not find the *workshops* beneficial for him and they did not encourage him to be critical, but he attended the workshops to gain more knowledge.

Example:

i. I *Every students are given the opportunity to attend workshop sessions, so have you attended the workshop sessions?*

SS07 *Yes*

I *Did this workshop session encourages you to be critical?*

SS07 *(_) No, they didn't encourage me, because I'm already encouraged. I'm already encouraged to think clearly of what I am doing, so there was no reason to for me to be encouraged by the workshop session.*

I *I think there're a few workshops for EE, EP, Maths, so which one do you attend, do you go for all three, or…*

SS07 *All of them, if I have some questions I ask the PGTA students, but mostly I was doing problem related subjects.*

I *But, you don't think the sessions helped?*

SS07 *It didn't help with critical thinking, it helped I don't know consolidating the knowledge, engineering subjects we were studying.*

(SS07_M_EU_Poland)

Individual Assignment and worksheets

Individual practice referred to module-based worksheets. Here, the modules which were mentioned the most by participants with reference to critical thinking skills were Routes to Success, Mechanical Science and Electric and Electronics.

Example:

i. *I find the EE and EP workshops are really useful…working on worksheets, I'll try to answer the question first before getting help from the instructors, yeah I do think the workshop sessions encourage me to be more critical.*

(SS11_F_UK)

Group work

Group was mentioned in the Stage One interview by just one participant, in association with a computer group project. However, this participant found another module even more valuable.

Example:

i. *The ones which <u>challenge me</u> the most would be the <u>most helpful</u>, and I think that Mechanical Science has probably has been really helpful in some certain aspects…computer applications I would say that the <u>group project</u> was quite valuable, but I'm not sure if I would evaluate that as being better than Mechanical Science module.*
(SS08_M_EU_Latvia)

5.6.7 Culture Category

The *culture* category was quite challenging to identify because most participants did not make direct reference to this unless it was incorporated in the interview question. From ten interviews' data only two responses made direct reference to *culture.*

Coding System for *Culture* Category

(i) Academic culture

5.6.8 Academic Culture

The cultural differences observed and experienced by the participants 'related primarily to their immediate social environment as students, i.e. to *academic culture*. Themes included getting used to new kinds of course requirements and rules, adapting to less international educational environment, and the challenges of integrating with younger or less experienced classmates.

Examples:

i. *It's a <u>new experience</u> for me. I face some difficulties at the beginning of the year. The <u>education system here is different</u>, I mean the university is different where if you fail a module or two the maximum you can retake in my country is three, but if you've retaken them and you didn't pass you can retake them for the next year like the American system. In my country you have to pass some modules in order to download other modules, like you can't study Maths B or C without A, so you have to pass A.*
(SS02_M_I_Libya)

ii. *The <u>cultures</u> are very different, what I'm used to obviously going to an international school then living in Dubai which itself is an international hub. Going from that to less*

internationalism, if there's a word? You know one coming here and then adapting to the culture here and learning, I mean the ways that are common here, things like that, and that's what different.
(SS01_M_I_Bahrain)

iii. *I admit I have like patience problems, I have problems with being patient around and you know other students are very young, 18 years old and the PGTA's as well, you know it's the biggest struggle of the foundation year, getting to whole mature and immature culture clash more than the lectures and more than the material. That is the number one struggle more than the learning objective. It's like when you try to do something for everyone, you're not gonna help everyone, you gonna try put everyone in the box, you can't definitely do that with me.*
(SS13_M_USA)

5.7 Summary – Stage One

Knowledge and *Attitude* on CTs are predominant categories for all participants in the Stage One interview. In the *Knowledge* category participants clearly showed they have pre-existing knowledge on CTs, which was broadly defined. Participants' definitions varied from one and another and were both philosophical and scientific. The philosophical approach to defining critical thinking were *critical evaluation, making clear judgment, self-correcting, thinking independently*, and *conscious thinking*. The scientific method of thinking were *problem solving, scientific thinking, productive thinking, analysing and synthesising* and *objective evaluation*. Based on the definitions given there were no significant differences within or between the groups. Participants' definitions varied which shows they tried to relate their own learning experiences to define critical thinking in a broader sense than specific to engineering. This may be due to the fact that participants were at the foundation level of engineering studies and would have not been exposed to skills which are subject-specific to engineering.

The *Attitude* category showed a general agreement among the participants that they were satisfied with their learning in the FY programme. However, it is still unclear about the use and its importance in the FY based on their differing definitions. At this stage of the research (Stage One), it is difficult to determine whether participants have developed the skills.

The research hypothesised that *English Language* and *Culture* could play a major role in participants' learning of CTs, however, the Stage One data clearly shows this is not the case in an engineering context. Participants were noted only mentioning language and culture unless raised by the researcher/interviewer. Interestingly, language takes different forms in engineering education as *numerical language* in mathematics and *programming codes* in computer application as defined by participants. For *Culture*, participants use it to describe *academic culture* moving away from how it is generally used in Social Sciences and Humanities as social practice rooted in social beliefs and norms of individual societies.

Overall the Stage One interview shows some difference between groups in defining critical thinking skills. The UK native group conceptualised CTs as *problem solving* skill, whereas the European group were able to produce a wide range of interpretation of critical thinking skills including *problem solving*. The international group's understanding of critical thinking was focused on *critical evaluation* and *analysing and synthesising*. It was evident from the analysis that FY students at this stage were able to define critical thinking based on their *previous knowledge*. Students were also were able to respond to CTs and the FY programme with a *sense of importance*, *satisfaction*, and also with some *frustration*, however, the majority of the students expressed *satisfaction* with the programme and their opportunity to *practice* CTs in the FY programme.

A sample Stage One Interview data is given in (*Appendix I.1 on p 282-296*).

5.8 Stage Two Interview

Stage Two interview involved student participants and was conducted immediately after their final year FY examination in June 2015. The rationale for the interview being conducted immediately after the examination was to capture students' views as exam candidates to find out to what extent the content knowledge of the EFY modules were tested with critical thinking skills.

Students sat a two hour written examination on four main engineering modules; Mathematics, Mechanical Science (MS), Engineering Principles (EP) and Electricity and Electronics (EE). However, students in the Language Pathway programmes A and B only took one module, either EP or EE. English for Engineering was one of the core modules for students in the Language Pathway programme. Therefore, students in the Language Pathway programme A took English for Engineering, Mathematics, Mechanical Science (MS) and Engineering Principles (EP) while Pathway B students took English for Engineering, Mathematics, MS and EE. The rest of the FY students took all the four main engineering modules which were Mathematics, MS, EP and EE.

The interview focused on students overall exam experience and sought to find out if the exam affected them in the same way or differently according to the different modules they took. The interview was also interested in finding out to what extent their knowledge and critical thinking skills were assessed, which modules required them to be more critical, to what extent participants applied their critical thinking skills in answering the questions, what types of thinking they applied in exam conditions and if it conflicted with critical thinking skills. The interview was also focused on finding out to what extent that academic English plays a role in answering exam questions. Other emerging aspects such as time management, preparations to answer exam questions and what makes a participant confident when taking the exam were also explored.

5.8.1 Development of coding system

The data was collected immediately after the final exam to find out to what extent students employ critical thinking in exam conditions, and to what extent students are assessed on their critical thinking skills. Data analysis was conducted using a combination of deductive and inductive coding and the recurring words and phrases were grouped into themes to identify the main categories. The interview will be analysed based on the following main categories:

i. Knowledge Category
ii. Attitude Category
iii. Language Category
iv. Practice Category
v. Time management Category
vi. Confidence Category

The data analysis shows some consensus among participants on their perceptions on the *Knowledge* and *Attitude* toward critical thinking skills in exam conditions. Their perceptions were largely influenced by the exam structure. *Knowledge* is noted to have direct connection with *Practice* and *Confidence. Knowledge* was pointed out with relevance to knowledge on content, theory and principles and the ability to use the relevant thinking and exam skills to pass the exams.

Attitude was largely present amongst almost all participants when discussing their experience in taking the exam and how it affected them differently based on the modules and previous exam experiences. *Attitude* was also mentioned together with *Practice* which were mostly positive expressions.

Practice and *Time Management* have often been directly connected. *Practice* is interconnected to pass exam papers and worksheets. It is linked with *Time Management* and it is expressed as *speed test*, *time saving* and *quick thinking*. It was repeatedly mentioned with *Practice*. *Knowledge* on content and theory of subjects learnt were frequently mentioned with *Practice*. *Confidence* was also used with *Practice* to answer exam questions.

Language is another main category expressed in the Stage Two interview. *Language* is expressed with connection to understanding exam questions and linked with *Knowledge* of critical thinking skills in exam conditions. Language was also mentioned with the *Attitude* category by both native and non-native participants on language as a medium of instruction.

5.8.2 Knowledge Category

In the Knowledge category thinking skills were mentioned to address different types of thinking applied in exam conditions. Types of thinking expressed were critical thinking, mechanical thinking, decision making, automatic thinking and criterial thinking. However, the term critical thinking is only mentioned directly by participants when used by the interviewer to pose questions using the term.

Coding System for *Knowledge* Category

i. Critical thinking
ii. Mechanical Thinking
iii. Decision Making
iv. Automatic Thinking
v. Criterion Thinking

Critical Thinking

Critical thinking was mentioned by participants in two ways, one as essential skills to understand and extract information from questions to solve the problems in the exam questions, and the other as an important skill to process and adapt new information.

Participants mentioned the importance and the application of *Critical Thinking* skills in exam conditions, claimed these skills helped them to effectively answer the questions well.

Examples:

i. *I think some of them were written explanation and some were calculation. I think all of them use some* <u>*basic critical thinking*</u> *from just reading the question and some required extra* <u>*more critical thinking*</u> *in order to solve the problems… If you don't understand the question how can you answer it in the first place?*
(SS12_M_UK)

ii. *SS10* *I think in EP, it was pretty heavy on* <u>*critical thinking*</u>*, and I think Electronics was the hardest in that regards. Everything is presented so differently this time,* <u>*so we take lot of critical thinking to actually break down the questions*</u>

and find out what is it you're trying to get … compared to past papers these papers this year require more critical thinking, I would say in my understanding of what critical thinking is … it's about eighty to ninety percent, you do get occasional define this that sort of question, that's not critical thinking question.

I *So, do you think if have acquired some of the essential critical thinking skills you would have done better in the exam?*

SS10 *Yes, of course, yeah*

I *In what aspect?*

SS10 *Drawing out the right information from the question, but that only came out couple of times but it would helped*

(SS10_M_UK)

iii. *Definitely <u>critical thinking I believe is necessary to attempt the questions</u> in every module… maybe it would have helped more if we were told explicitly that what critical thinking is and how to apply it and stuff because I believe I was applying critical thinking without knowing that I was doing so, and it still helped maybe it would have been more efficient if we had been taught about it and told how to apply it.*
(SS01_M_Bahrain)

In the *Knowledge* category *Critical Thinking* skills was also mentioned by participants in relation the type of skills required to process new information in the exam questions.

Examples:

i. *In EE, the question asked to design circuit…it asks you to not only use the skills but also show that kind of invent something from those skills observed, I mean taking the knowledge and putting in something new … it's <u>like applying all these knowledge to something new, something unseen that's why you need to think deeply to think through it kind of critically</u>…the rest of the exams in the foundation year has been designed, I would say in a very schematic way.*
(SS07_M_Poland)

ii. *The exam is more like a speed test like tests your already familiar with this, not if you eventually be able to figure it out the real answer, so it requires more training … it does <u>require critical thinking skills when have to do something that you never had before.</u>*
(SS08_M_Latvia)

Mechanical Thinking

It was noted that participants described *Mechanical Thinking* as the type of thinking needed in exam condition*s.* Participants expressed that critical thinking is needed in preparation for exam, but not when answering exam questions confined by allocated time. They expressed the opinion that critical thinking which needs deep thinking takes time, therefore mechanical thinking works better in exam conditions.

Examples:

i. *I think it's like you use your practical knowledge…and then showing that skills in the exam … for me it was kind of mechanical … because most of the questions are repeated because we have practised it, because we knew it we don't need much of critical thinking, it's just mechanical solution … we just apply the ready method not invent this method … in exam you don't have to think deeply, you just solve it … there's not much deep thinking behind the questions … which I actually find quite annoying, because it's like not a proper understanding, it's like mechanical thinking, but that's how the exam is designed.*
(SS07_M_EU_Poland)

ii. *It's obviously if you're really prepared the best you can you always going to see a question as similar and methods for doing everything … for me I was less prepared, so I was just sat and think about I didn't have that sort of mechanical thinking for every questions … but Mechanical Science he just reuses the questions all the times, like the questions are very similar, it's like mechanical, like regurgitating how you solve the last time, you see like twenty of the same questions.*
(SS11_F_UK)

iii. *The thing is that although many questions require critical thinking especially in EE, the thing is that the way it's tested as assessed it requires too much practice and mechanical thinking … you must have practised so much, that during the exam maybe during the practice you need the critical thinking but while the exam you just have to write like a robot.*
(SS06_M_EU_Greece)

Decision Making

Participants did not give any clear definition to what they meant by decision making but explained why decision-making skills are useful in exam conditions. The participants mentioned decision making in relation to time saving and collecting marks.

Examples:

i. *It's about <u>decision making</u> during exam. You can't answer all the questions, unless you're a tutor or something (laughs) … I mean just get marks for the questions that you're sure about and come back to those questions when you've the time when you've finished all the questions. Come back, when you're doing you revision. Come back to those questions and think about it. During exams I would skip these questions that require thinking.*
(SS02_M_Libya)

ii. *During the exam you must not think, must see and <u>decide immediately</u>, otherwise you have to leave some questions.*
(SS06_M_Greece)

Automatic Thinking

One participant mentioned automatic thinking to thinking used in exam conditions, again due to time constraints.

Example:

i. *it wasn't difficult for me to do them because I just targeted doing them <u>automatically like automatically knew what course of action</u> that I should take when they start changing things like they change the set-up of the questions even though they are based on same knowledge, you start to question what you have to do. It means you <u>automatically have to go through everything</u> that you know.*
(SS08_M_EU_Latvia)

Criterion Thinking

Criterial thinking is another types of thinking mentioned by one participant referring to the methodological process involved in thinking has resemblance to critical thinking skills.

Example:

i. *<u>Criterial thinking</u> … may be EE because it's not given directly, it's actually giving some data but implicitly. So, you have to compose a question and decide what is asked, what the best way to follow in order to reach the required result.*
(SS06_M_EU_Greece)

5.8.3 Attitude Category

The Stage Two analysis of participants' *Attitudes* on critical thinking skills was conducted by focusing on their perception of the use of critical thinking skills in answering exam questions.

Coding System for *Attitude* Category

i. Sense of uncertainty
ii. Sense of importance

Sense of uncertainty

It was noted participants expressed uncertainties when asked about the role of critical thinking in exams. This interview was conducted immediately after their exams, and they expressed uncertainty on whether they had done well in the exams. The participants talked about the importance of content knowledge and understanding of theories and concepts in connection with passing exams, but were uncertain whether critical skills would have had helped them in the exam.

Examples:

i. Some questions required time, it looked difficult when you first look at it but when you think about it, it's not difficult but it needs time, as I said it was different. You have to understand the content, if you don't understand you can't just memorise the past year exams papers and write down everything. So you have to understand the theories … you can't just memorise the formulas and put in the numbers.
(SS06_M_EU_Greece)

ii. I think the exams … like I really felt challenged … all these questions most of them I hadn't have seen anything like them. Okay, I'm sure that's on purpose. But, every single exam I felt like 'man! There's a trick here, and sometimes I felt that there are these questions were being just little like. Ah! (_). I don't know how to say it. The wording was like very easy to get the problem wrong if you don't know exactly what they're asking … But, there are some tricky some of these questions were also like a little like 'mind binder' is the right word.
(SS13_M_USA)

Sense of importance

The importance of critical thinking skills in exams was coded by most of the participants. Some students made observations on their exam papers and claimed that the papers were designed differently with more focus given on critical thinking skills they realised the importance, but uncertain if that much of critical thinking was required at foundation level exams.

Examples:

i. Everything is presented so differently this time, so we take lot of critical thinking to actually break down the questions and find out what is it you're trying to get … compared to past papers these

papers this year require more critical thinking, I would say … it's about eighty to ninety percent, you do get occasional define this that sort of question, that's not critical thinking question, I don't know at this level we really have it tested quite the depth.
(SS10_M_UK)

ii. *I would say all of them use some basic critical thinking from just reading the question and some require critical thinking in order to solve the problems.*
(SS12_M_UK)

(iii) *In terms of critical skills … yes definitely … I did preparation with papers questions I think I got quite confident like … completing a question when I had my notes and everything but I don't think I understood the logics behind it, like the methods behind it. So, I when I went into the exam with a different situation it was much harder … I think adapting to difference to questions I think it quite important, sort of analysing the basics of what they're asking and seeing sort of how you'd solve that … so if it's about heat transfer, so how I solve that question…which may worded differently but sort of needs sort of similar skills that's required.*
(SS11_F_UK)

5.8.4 Language Category

The codes appeared in the Stage Two interview analysis in the *Language* categories are *wording and phrases* and *English*. For English category only one participant (SS09_M_Cyprus) made a direct reference to English as to the English for Engineering exam paper. This is also the sole participant following the English Pathway course who had to take the paper as a core paper. In this same category another participant (SS02_M_Libya) indirectly referred to English as to being a non-native user of the language.

Coding System for *Language* Category

i. English
ii. Words and phrases

English

The participant was a non-native speaker with hearing impairment who reported having a problem completing his exam, not mainly because of the language but the topic was irrelevant to his own context. In his comments English was identified with written language and quality of language academic vocabulary was seen as the main assessment criterion.

Examples:

i. *I 'attended' the English, so at the moment I 'attempted' all the questions, but I left the last questions half … because not enough time … because the subject is not my interest area … it was taken from the Mechanical Science, but it was about a loud speaker. So, I'm not interested in a loud speaker because I'm deaf (laughs). So wasted a lot of time … I can say it was not a good exam, but if it was on engine … or rocket or plane it would have been much better … at this moment they give loud speaker (laughs), at this moment I've loud speaker in my ear. I've never wondered how it works (laughs) … because I was thinking what would be appropriate because I know my teacher was expecting me to write academic words, she expected us use lots of grammar, vocabulary but this moment it was not performed.*
(SS09_M_EU_Cyprus)

ii. *it's not my language so, I might not know every word, that is an issue.*
(SS07_M_Poland)

Words and phrases

Four participants made reference to *words and phrases* when explaining difficult questions. From the four participants two were native speakers. The difficulties of the exam questions were linked with longer text and wordy questions. Worded answers and reading long text were viewed as more difficult than dealing with numbers in mathematics problem solution according to one participant (SS11_M_UK).

Examples:

i. *They did say that this year exams may test on knowledge more like understanding … so, they wanted answers like worded answers explaining like the definition of something or explaining how something works…longer questions were harder than I expected … lot of written questions in, like explain how a transistor works and stuff … I'm not fan of words (laughs) … you sort explain how something works, I'm not great at expressing myself (laughs) … that's why I'm more comfortable with maths, "Oh! I've an equation I'm gonna put some numbers in it and I figure it out.*
(SS11_F_UK)

ii. *Maybe it was asking for the same thing but the way it was phrased may have put be me off … when I come across a question with lot like two paragraphs before even I start I'm immediately like not interested in it because I have to read a lot. I prefer one to two sentences, I don't mind the difficulties. I just prefer shorter sentences and less words.*
(SS01_M_I_Bahrain)

5.8.5 Practice Category

Practice here referred to practice on past exam papers. Doing a lot of practice prior to the exam was seen as helping students to do well in exams. Almost all participants find sufficient practice is needed to cope with exam conditions. Familiarity through practice, and time management were seen as important in exam conditions in order to pass the exam.

Coding System for *Practice* Category

i. Practice

Practice

Examples:

i. *The thing is that although many questions require critical thinking especially in EE, the thing is that the way it's tested as assessed it requires too much practice and mechanical thinking … especially Maths because I know that's the only one I wrote all the questions and I think I did well, because I studied well and practise through the semester. I think that is what I did Maths and I barely make it in time, I didn't stop writing.*
(SS06_M_EU_Greece)

ii. *The exam is more like a speed test like tests you're already familiar with this, not if you eventually be able to figure it out the real answer, so it requires more training.*
(SS08_M_EU_Latvia)

5.8.6 Time Management Category

Time Management was coded as *time saving, under pressure* and in the data analysis. Four students made direct reference to time and working under pressure in exam conditions. From the four participants one participant (SS10_M_UK) explained he was good at managing time therefore he was not working under pressure as the rest of the three participant, (SS01_M_Bahrain), (SS11_M_UK), and (SS08_M_Latvia). One of the participant, (SS01_M_Bahrain) linked time management to critical thinking skills in which having the skills would have saved him time and he would have answered all the questions confidently and not having to rush to finish the exam paper.

Coding System for *Time Management* Category

i. Time saving
ii. Under pressure

iii. Speed test

Time saving, Under pressure and Speed test

Examples:

i. I *So, how was the exam?*

SS12 *It went on alright. I think I covered all the materials and before I could it and did make a few mistakes in the exams* *__under pressure__* *and (_)*

I *So, it was okay*

SS12 *Yeah*

I *And what was not okay?*

SS12 *I just* *__don't work well under pressure__* *and exams are quite stressful. It's so easier to make small little mistakes*

(SS12_M_UK)

ii. *For me personally, I think the biggest issue is how long it takes me to do everything because for me it felt more like a* *__speed test__**, basically.*

(SS08_M_UK)

Almost all the participants talked about the time pressure when answering the exam questions, however, there was one participant, (SS10_M_UK) who mentioned that he was good in time management and explained how he would have dealt with the issue.

Example:

i. *I'm quite good at that. I'm actually very good at that because the timing for the papers is very good they are generous enough at that.* *__With a 100 marks it's a 2 hour__* *exam well they were all are and* *__that is sort of 120 minutes__*. *__I set myself a mark a__* *__minute which gives me twenty minutes in the end__*. *When I if I fallen a bit behind I still have that* *__20 minutes back lock__*. *So, yeah I can do that fairly well. Again that practice with past papers really.*

(SS10_M_UK)

Confidence Category

Confidence Category was coded in the analysis together with *Practice Categories* and *Knowledge Category*. Three participants mentioned, 'confidence' in the Stage Two analysis. One participant mentioned confidence in connection with practice before the exam, (SS11_F_UK). One participant mentioned confidence with knowledge in the term of critical thinking skills, (SS01_M_Bharain).

Examples:

i. *I've done lot of revision with past year exam questions and I think I got quite confident like completing a question when I had my notes with me and everything but I don't think I really understood the logic behind it. Like the methods behind it. So, I when I went into the exam with a different situations it was much harder.*
(SS11_F_UK)

ii. *Currently what I felt was you answered one question and then you had to at least spend thirty seconds looking at the second question and seeing how would you approach it recalling all the things related to it with the critical thinking acquired all these might have been done much quicker … and also confidence, we feel confident yes that we're applying and once we're done, I mean you can acquire and answer in the exam but there's still that feeling that is it even the right answer, that did I approach the question correctly.*
(SS01_M_Bahrain)

5.9 Summary – Stage Two

Knowledge and Practice categories were mostly mentioned in the Stage Two interview. Concerning Knowledge, participants used different terms to describe the thinking process involved in exam conditions. The terms used were, Mechanical Thinking, Decision Making, Automatic Thinking, and Criterial Thinking. Some participants pointed out that in exam conditions critical thinking is not required but believe critical thinking skills are useful when trialling out previous exam papers as preparation for the exam. However, there was a significant difference between groups on their attitudes towards critical thinking skills in exams. Almost all the UK and US participants claimed that critical thinking skills were important in exam conditions in understanding and analysing questions, and in the approach to answer the questions as compared to most international and EU participants except for one participant from Bahrain (SS01_M_Bahrain) who has studied in British Curriculum for his International Business Baccalaureate. However, two of the EU participants (SS07_M_Poland) and (SS08_M_Latvia) also agree critical thinking skills are important in exams but not necessary to pass the exam.

Practice categories were frequently mentioned by participants as important in preparation for the exam. Almost all participants related practice to understanding of the subject matter including content and theories and its importance in answering the exam questions. This is how they explained the importance of practice on previous exam papers.

Language categories were least mentioned by participants. Participants including first language (L1) English speakers mentioned that interpreting question wording and drafting verbal answers were quite difficult as compared to other forms of answers, for example mathematical solutions. One non-native participant commented on the English language exam paper which was an issue for him to answer because of the content rather than the English itself.

On the whole there were no significant difference within the group in most categories except for the Attitude category with reference to critical thinking skills. It seemed the UK and US participants valued the importance of critical thinking skills in exam conditions more greatly as compared to non-native participants except one international participant from Bahrain (SS01_M_Bahrain).

A sample Stage Two interview data is given in (*Appendix I.2 on p 297-317*).

5.10 Stage Three Interview

This report presents the Stage Three interview, which is the final qualitative interview data of a year observation, which explored students' perceptions and understanding of critical thinking skills for engineering and their development during their FY. The participants participated in the interview were EFY students from cohort year 2014-15.

Stage Three interview were conducted at the beginning of Semester Two, academic year 2015-16. At the time of the Stage Three interview, participants have completed their FY and were in their 1st year of their engineering undergraduate programme, academic year 2015-16. For the Stage Three interview, participants were asked to respond to questions about their attitudes and understanding of critical thinking skills based upon their experiences as FY and undergraduate engineering students. Questions on effective classroom practice and assessment on critical thinking skills were also asked. To find out if the participants have learnt and developed academic critical thinking skills during the course of a year, they were also asked to what extent they believed language and cultural background affect their learning and acquiring critical thinking skills for their engineering study.

5.10.1 Development of coding system

Similar to Stage One and Stage Two interviews the research questions were used to identify the main categories and themes to analyse the data. The Stage Three interview questions were mostly similar to Stage One interview with one new topic on, 'assessment' on critical thinking included. A question on, 'assessment', was included to find out if participants will be motivated to learn the skills if they were assessed on critical thinking skills before they graduate as engineers.

Based on the final ten participants' interview data, the following main categories and subcategories were identified.

Main categories:

i. Knowledge
ii. Attitude
iii. Critical Thinking Experience
iv. Assessment
v. Language
vi. Practice
vii. Culture

The data analysis shows *Knowledge* and *Attitude* have some obvious similarities and differences which were largely connected to *Practice* in general and participants' experience in their FY.

Practice has often been interlinked to engineering modules, group work and projects. *Practice*, *Attitude* and *Assessment* were noted to have some connection with the two sub-categories, *Independence* and *Motivation.*

Language has been often interconnected to language as a communication tool as in spoken, reading and writing in English. Besides that, language in an engineering context is also interpreted as fluency in mathematics and computer coding language but rarely mentioned. *Language* is also referred to as participants' first language.

Critical Thinking Experience is largely connected to family influence, Engineering Foundation Year and previous schooling. Critical Thinking Experience has also some connection to *Knowledge, Attitude* and *Culture. Critical Thinking Experience* is discussed with participants' learning experience before and after FY.

Culture is perceived with a broader understanding as society, learning culture and British culture. Culture is noted to have some direct connection with *Critical Thinking Experience*, which referred to family influence and previous schooling experiences. The analysis show significant similarities between groups based on their connection to family influence.

Assessment is another category that has direct links to *Practice* and *Attitude*. *Assessment* and is also noted to have connection to sub-category Motivation.

Overall, the critical thinking skills pointed out by the participants have close relationship with main categories *Knowledge*, *Attitude, Critical Thinking Experience, Practice* and sub-category *Independence.*

5.10.2 Knowledge Category

Knowledge category for the Stage Three interview relates to the participants' developed knowledge on critical thinking skills for engineering. This category analysed how participants define critical thinking skills based on their FY and engineering student experience. Almost all the participants have narrowed down their definitions mainly to *problem solving* as critical thinking skills for engineering except for two participants, (SS06_M_Greece) and (SS13_M_USA) who differed from the rest found in the analysis, *Problem solving* was the most frequently mentioned interpretation of critical thinking by the participants. Eight from the ten participants defined critical thinking skills as *problem solving*. Three participants interpreted critical thinking as *picking up the truth* and *sourcing*. Participants also mentioned *independent thinking*, *consider other point of views*, *learning how to think,* and *life skill* to define critical thinking skills, however these were the least mentioned by participants.

Coding system for *Knowledge* Category

(i) Problem Solving
(ii) Picking up the truth
(iii) Sourcing
(iv) Independent Thinking
(v) Different point of views
(vi) Learning how to learn and think

Problem Solving

Problem solving is the most frequently mentioned by participants to define critical thinking skills with reference to their engineering study, and real life situation. Engineering module Maths was most referred to as problem solving as critical thinking skills. Participants were able to explain in detail in defining their understanding on critical thinking as problem solving skills. Two of the participants (SS08_M_Latvia) and (SS10_M_UK) mentioned problems need to be created first before solving a problem, and one participant (SS02_M_Libya) expressed that there is no single way to solve problems as critical thinking skills.

Examples:

i. *My perception I think has changed … it's more about the skills, it made me like, consider there might be some other points of view, and most of them are right, and there isn't a single way about going to specific problem. You can generate some other ways of solution just by trying to analyse the results and you come up with your own way of solving it.*
(SS02_M_Libya)

ii. *I would define critical thinking skills as being able to extrapolate the necessary information for you to start creating a framework for a problem and then solving it in a manner that is efficient and logical.*
(SS08_M_Latvia)

iii. *I still say solving problems, finding solutions in difficult situations and add to that now is coming up with new things, is creating scenarios of your own in solving them. Creating a problem of your own and solving them, previously, I just thought it's just problem solving now it has changed.*
(SS10_M_UK)

iv. *I would say to use critical thinking to tackle tasks…I would say we had to first look at what the task is demanding of you, then think about what you need to do to attack those certain problems then relevant solution and methods to tackle the tasks.*
(SS01_M_Bharain)

v. *To see tricky things in a question. For example, you're given a question and how do you solve the question, firstly, you have to discriminate the important things in the question. Without the important thing you can't solve the problem … at the moment to find the weakness in the system…when I find the weakness I try to fix … when I find the weaknesses I say I write down I take note this is the critical point of something. For example, if we're talking about a gear system and if the calculation shows us the system were failure under this focus point I try to find out what kind of problem.*
(SS09_M_Cyprus)

Two participants (SS12_M_UK) and (SS07_M_Poland) relate problem solving skill to life skills as critical thinking skills as transferable skills to various context. One of the participants (SS12_M_UK) also admits that it is difficult to define critical thinking skills, but was able to explain in detail how critical thinking skills are transferable.

Examples:

i. *It's hard to define what they actually are, skills like problem solving, to be able to communicate your work to other people well, almost like a life skill in a way. There's lots of application at the same*

problem solving skills that can be applied to science, engineering or any problems that you have. So, I think it's sort of being able to find solution to any problems using the same skills for engineering.
(SS12_M_UK)

ii. *It's still important, it's not just purely apply in engineering. It's a transferable skill. So you can apply critical thinking in many ways like problem solving in terms of mathematical, problem solving in terms of you know if something happens to your life, you need to think clearly what to do. Yeah, it's the same and it's still important for me, I would say.*
(SS07_M_Poland)

When participants interpreted critical thinking skills as *Problem solving* skills it was noted participants mentioned problem solving together with the need to identify tasks and formulate questions first before solving problems.

Picking up the truth

Participants also attempted to define critical thinking as picking up or *identifying the truth*. Two participants (SS13_M_USA) and (SS06_M_Greece) find critical thinking as skills used to seek the truth.

Examples:

i. *It means picking the accepted truth … not accepting what's given (laughs) … I wish I could learn, you need to learn the truth before you could challenge it. So, I'm not just trying to be contrary, I'm not trying to be ironical or I'm trying to pick up a fight … I need to stop to questioning, I need to stop being critical. I need to accept more. I just need to stop being so difficult (laughs).*
(SS13_M_USA)

ii. *My critical thinking is examining why something is true or not based on logic … I'm starting doubting everything in more in-depth than what I was doing back then … it reaches a point that like a bit annoying. I'm losing a point of reference in genera l … like Maths, I'm trying to prove something that way. Something else expresses the other way. I'm trying to combine the definition, then the third thing comes up. I'm like where does this come from and that adds more and more never ends … sometimes I found myself saying, okay, now we need blind belief not critical thinking, no more … just believe what you see or told, otherwise you're gonna lose it (laughs).*
(SS06_M_Greece)

It was noted in the analysis that participants (SS13_M_USA) and (SS06_M_Greece) expressed their frustration in their attempt to seek the truth to a stage where both the participants mentioned that they need to stop being critical because they find it quite annoying and being difficult. However, both participants laughed when they mentioned that they need to stop being critical which could be they are trying not to be too serious about their views at the time of the interview.

Sourcing

Looking for information, or *Sourcing* was also used by participants, when asked to interpret critical thinking skills. Participants mentioned sourcing out relevant information to solve problems as part of critical thinking skills.

Examples:

i. *I would define critical thinking skills as being able to extrapolate the necessary information for you to start creating a framework for a problem and then solving it in a manner that is efficient and logical.* *(SS08_M_Latvia)*

ii. *Part of critical thinking is sort of learning where to get the information from like if you tackling a problem, learning sort of understand it and where to find that information is like, that's what we learnt last year with worksheet and stuff. If you're given a worksheet and look back in our own notes and sort of go to the tutors and ask for help, so this year that helped me a lot because if I don't know how to solve a problem I look like example answers, and I go back to lecture notes if there's example. I think that's the main skill that I'm using this year, like sourcing.* *(SS11_F_UK)*

iii. *Trying some other sources, trying to coming up with the problem differently, and you can make up or look up in the internet, like the sheets that you have on the Blackboard you can just look up everywhere, think about different sources, different ways of solving things.* *(SS02_M_Libya)*

Independent thinking

Independent thinking is another interpretation of critical thinking, which is connected to *Knowledge* and *Practice* mentioned by one participant (SS02_M_Libya). The participant mentioned Independent thinking to relate to experience, sourcing information independently to solve a problem in an academic context.

Example:

i. *Thinking independently and come up with solutions that you think is better than the other. (SS02_M_Libya)*

Different point of view

Participant also use *Different point of view* as critical thinking skills, which is mentioned with group work.

Example:

i. *Could be different point of view when comes to critical thinking. When you like working in groups someone might say something and you either criticise it or you like constructively criticise it. (SS02_M_Libya)*

Learning how to learn and think

Learning how to learn and think is a phrase one participant used to define his understanding of critical thinking.

Example:

i. *Critical thinking is about learning how to learn and thinking about how to think. (SS06_M_Greece)*

5.10.3 Attitude Category

Participants' attitude towards critical thinking skills and their development through the foundation engineering year was conducted by looking at their views and their experience as FY and engineering students during the course of a year. Participants' views on critical thinking skills for engineering study were coded using this main category.

Coding system for *Attitude* Category

(i) Sense of importance
(ii) Sense of satisfaction
(iii) Sense of uncertainty
(iv) Sense of frustration

Sense of Importance

Participants' attitudes towards critical thinking skills and their learning experience in their FY programme is coded when participants shared their experience in critical thinking as engineering students. Participants were asked whether they find that critical thinking skills were useful and important in their foundation year. Almost all the participants responded that critical thinking skills were important and they used positive comments to share their experiences. Participants relate their learning experiences and critical thinking in their foundation year to its importance to their first year of engineering undergraduate study.

Examples:

i. *I would say that the importance of critical thinking skills in foundation year compared to this year are about the same I would say but, that doesn't necessarily mean for every other course because, I think there are some courses that can be more challenging like Electronic Engineering.*
(SS08_M_Latvia)

ii. *I think I end up using in mini projects that I had to at the moment or labs, require quite a few skills especially analysing results and how to interpret things, paying attention to details, lots of things rolled up into one (laughs). Just more details than what I've done on the foundation year … the mini project that I'm doing at the moment is exploring fuel cells.*
(SS12_M_UK)

iii. *I think it's just as necessary and the, it helped, my idea of critical thinking back in foundation year is the same, like my critical thinking of a foundation year has helped me like adapt to the first year, so I would say that was quite helpful and yeah I would say more or less a same. Is just the way you approach question, for example any tasks in the first year.*
(SS01_M_Bahrain)

Two participants (SS11_F_UK) and (SS10_M_UK) expressed that they were more aware of the importance of critical thinking skills, which they had applied in their foundation year now. (SS10_M_UK) mentioned his understanding of critical thinking has changed now. He found now it is more of a pragmatic thinking rather than just related to mathematical thinking.

Examples:

i. *I think half engineering you got to have critical thinking skills like whatever you do. I'm sort of far more aware of how important they are, like much I do use them, but I may have done something in the same ways, but I'm more aware I'm using critical thinking skills and why I need to do that.*
(SS11_F_UK)

ii. *I think it has changed. Previously, I thought critical thinking skills were more related to mathematical skills and it's actually language based, problem solving. So, applying the features of maths and thinking around mathematical way to solve them I had to think differently about them. I think now I'll take more pragmatic approach to critical thinking. Let's say it's less about sort of abstract*

thought processes it's more about interest in finding an answers in many a times. So, particularly in engineering just doing a research finding out what you need to know you need to really apply lot of critical thinking. It's a bit more of finding the answer and a, yeah, that's it. It's little bit more down to earth.
(SS10_M_UK)

One participant mentioned critical thinking is important and relates its importance when dealing with exam questions.

Example:

i. *I think critical skills is important for engineering … for foundation year because you can see you questions and see the problems and solve the problems, and sometimes exam questions can be tricky.*
(SS09_M_Cyprus)

One participant relates the importance of critical thinking to innovation and creation, and how it is important in helping in identifying what one knows and does not know.

Example:

i. I *So, do you think critical thinking is important for foundation year?*
SS13 *Yeah, well if you don't have critical thinking skills you won't question what's been previously accepted. There won't never be any change in innovation or creativity in you, if not for critical years of works you're gonna miss for small little errors that everyone assumes is correct.*
I *Small little errors, what you mean by that?*
SS13 *Like you know like the unit conversions, or just like the, you know Einstein wasn't right about everything.*
I *Are you talking about the details?*
SS13 *Okay, sure. Or, even bigger things. Okay, sure details is fine, like people are really good at details, but maybe you know like things like people just assumed, you know nobody ever thought that … you know, there's things that you know that you don't know.*
(SS13_M_USA)

Sense of Satisfaction

Participants' attitudes towards critical thinking skills and their experience using the skills were coded when participants gave positive feedback on their learning experience in the FY and as engineering students.

Examples:

i. *Throughout the course you apply them you realised that is critical thinking. The way the system works here, the education system in this university makes you, like come up with your own answers, come up with your own work doesn't make you rely on the lecturer's way because sometimes even the lecturer's way there's some puzzle there. You think like, it doesn't make logical sense, you come up with your own way. It makes you go out and research, and go out to internet and look for something and ask some others for this topic to get some knowledge. That will gain you by time some critical thinking skills because you start generating new solutions and analysing data (laughs). (SS02_M_Libya)*

ii. *I think critical thinking skills when I first started foundation year was just sort of what I learnt from school, like look at the text find the key points and then use them. Whereas now, you got to think more of like whether the source is reliable and sort of how to use, how to find different source for you and sort of comparing as well … a lot more detail … I'm much more aware now that I'm applying critical thinking skills. Obviously, I'm like give them a thought like in the past year…now I'm more aware when actually using them … I'm just more conscious that I'm using them, that I'm using what I learn.*
(SS11_F_UK)

Participants who expressed their satisfaction in the FY programme and their exposure to critical thinking skills mentioned that what they learnt in their FY they were applying them in their undergraduate programme and were more aware that they were using the skills in their studies.

Sense of Uncertainty

Although almost all participants agreed that critical thinking was important in their foundation year, one participant expressed it was important but hard to find a basic tool as base for his critical thinking. He also mentioned he was uncertain, which was the safe way of thinking in both science and life as well.

Example:

i. *I realised how critical thinking is more and more important in life … I find it hard to find a basic tool on which I can base my critical thinking, and I think that's the hard part. That's the basic methods of thinking in science, scientific way of thinking, what's the safe way of thinking, like in life as well. (SS06_M_Greece)*

Sense of Frustration

Sense of frustration is coded when participants express dissatisfaction with their performance and the use of critical thinking skills in their studies and academic life. Participant's frustration is also expressed when they question themselves if they need to be critical because they felt they are being quite difficult and the critical thought processes were quite annoying. However, only two participants from the ten who participated in the interview expressed their frustrations related to critical thinking skills in their studies and academic life.

Examples:

i. *I for some reason I feel that the further you progress in your years at uni the <u>less critical</u> you're able to be. I don't know why, like maybe you just because you just don't have that practice, and you don't want to have better attention to be seen as different. I mean it's very much in architecture, you don't want to do anything radical or different because the establishment, you know, they don't like change … I kind of shock … I don't see many kind creative or new ideas from people as they get older, that's the way it is.*
(SS13_M_USA)

ii. *I think theoretically my perception hasn't changed … but <u>apply more details</u>. My idea of critical thinking is about the same, but the way I apply more in-depth. So, I also find it a <u>bit difficult</u> to apply the skills in many cases. …. May be something is added, which I believe have changed … I just used it in-depth generally … my critical thinking is examining why something is true or not based on logic <u>… I'm starting doubting</u> <u>everything</u> in more in-depth than what I was doing back then … it reaches a point that, like a bit annoying. I'm <u>losing a point of reference in general</u> (laughs).*
(SS06_M_Greece)

Both the participants (SS13_M_USA) and (SS06_M_Greece) who expressed their frustration also mentioned in the interview that they did not do well in their FY examination, and were either repeating some modules or repeating the FY programme. Their frustrations is expressed in relation to their performance in their FY examination and the restriction they encountered when they tried to be creative and innovative as engineering students.

5.10.4 Critical Thinking Experience Category

Critical Thinking Experience Category analysed participants' previous education and critical thinking learning experience as compared to then and now as engineering students. Stage Three interview focused on participants' experiences in critical thinking skills having completed their FY programme.

Coding system for *Critical Thinking Experience* Category

(i) Critical Thinking Experience in School
(ii) Critical Thinking Experience with Family

(iii) Critical Thinking Experience in FY

Critical Thinking Experience in School

Participants experience in critical thinking in their previous schooling is coded when they mentioned their experience in critical thinking related to their educational system, teachers' role in class, subjects and examination.

Almost all participants mentioned that they did not have sufficient opportunities to practise critical thinking skills in their previous schooling, except one participant (SS01_M_Bahrain) from the ten participants interviewed.

Example:

i. SS01 For me personally, it has always been there. I was brought up in Bahrain, went to school to a British school from the start obviously … more open minded, and was encouraged… I was always have been encouraged to be open minded, think critically, to think outside the box … and obviously the country where I was brought up in, both Bahrain and Dubai they not very, what can you say, conservatives when comes to like education.

I Can you think of something, there must be something that was exciting that you did, and to think of it now you realised, 'oh, that's critical thinking'?

SS01 In high school?

I Yeah, could be in your previous learning.

SS01 They do it in a way, for example, we had an experiment with a ball launcher.

I ball launcher?

SS01 Yeah, and it was, I remember it was our first lesson on it and we were given a task, for example at what angle would the ball will fly the furthest, and that obviously involved critical thinking. Because, you obviously have to have a good guess vertically up or horizontally down. That, now to think about it involved critical thinking.

(SS01_M_Bahrain)

Three participants (SS10_M_UK), (SS11_F_UK) and (SS08_M_Latvia) mentioned they had opportunities to learn and practice the skills but minimal, either limited to certain subjects or some teachers who took efforts to teach the skills, while the rest of the teaching was largely exam oriented.

Chapter 5

Examples:

i. I *How about your learning background? Were you consciously aware that you've been encouraged or to think differently or independently, and there's always opportunity for you to apply critical thinking skills in your previous learning?*

SS10 *I'd never taught that…I've never aware of that. I never knew any of that, I didn't go to particularly a good school, but it wasn't a bad school, you know very mediocre. Yeah, there wasn't much of that.*

I *Do you think this is an isolated case, or do you think it's in general?*

SS10 *No, I think it's in general. Maybe I'm just not remembering well.*

I *In your 6th Form, how was your student experience, was it very independent, lots of critical thinking, lots of projects which promote critical thinking that kind of things?*

SS10 *No, we didn't (laughs). No, it was still very much the same. I was very much conscious that we were taught to past year exams.*

I *So, it's very much exam oriented?*

SS10 *Massively, completely … occasionally a teacher would, you know make an effort to do something different. We had like my chemistry teacher she certainly tried to, you know she set a project at one point where you can just research. There's an element of research, it was great … I think, that's the only thing I remembered we did properly, I think.*

(SS10_M_UK)

ii. *No, I think the whole way moving on to college, but in school they did do classes on some critical thinking skills … not a heavy part of our curriculum. Maybe a couple of lessons a month or something that fit so many skills, which is really useful, especially like sourcing, like evaluating references and stuff. But, in college we sort of memorised. Like, our teachers will give us sort of typical questions and tell us to memorise the answers, and then in exams pretty much the same questions come up … like my school is just like private all-girls school. They fix on other skills as critical thinking skills. But then, at college it was very much just memorise information given for exams … it's like there was a big difference in the way they were taught.*

(SS11_F_UK)

iii. I *In your previous education did you have a lot of opportunities to apply critical skills or is it about the same as now, or do you find it different?*

SS08 *I think there's more opportunities now than before*

I *You have more opportunities now?*

SS08 *Now, I've progressively improved.*

I *Okay, so did it…*

SS08 *Yeah, high school. I think in comparison I did not put enough effort in high school at all.*

I *In teaching, in classroom practice did you have enough practice in your previous education?*

SS08 *To an extent, but I think comparatively I weren't.*

I *So, you're getting more now?*

SS08 *I think to an extent, yes. I think so.*

I *Umm, can you give an example in your previous learning that you've learnt critical thinking skills consciously?*

SS08 *Yeah, for example, in Economics we had some projects, where you just logically decide what business ideas will be viable in certain situations, or I also had research project about sea port and how you could attract more cargo to it. But, it kind of spread out in small doses. I think it would have been easier for me like the stuff I had in my foundation year I already have when I was sixteen or fifteen. I think that would have helped me quite a significant impact in a positive way.*

(SS08_M_Latvia)

One participant (SS09_M_Poland), mentioned the only time he could recall he had experienced critical thinking skills in school was in exams with questions on understanding and evaluating texts.

Example:

i. *I wasn't aware before that there's something call critical thinking skills. You know, maybe teachers were aware about it, but they just didn't bother to make us aware. Because they were embedding cleverly those skills giving some problem … for example like preparing for the final exam in my language, my mother language Polish. I had to practice skills like understanding the text it was called, 'reading with understanding', it was critical thinking skills. We were practising these skills, but were not calling it critical thinking skills. We were calling it just you know, practising for final exam that particular skills … I think it's particularly important to be able to read and evaluate. (SS07_M_Poland)*

Two other participants (SS06_M_Greek) and (SS09_M_Cyprus) when asked about their experience in critical thinking skills in schools linked their experience with either scoring or passing exams.

Examples:

i. *My first language is Turkish and I was taught in Turkish educational system similar to Turkish educational system…everything is given to us is step by step system. Teacher teach us step by step you just focus on the score and listen to the lecture.*
(SS09_M_Cyprus)

ii. *In school, my educational system I think doesn't support critical thinking so much but still was getting good grades just by memorising and having to go through it again and again … the education system doesn't support, even the science didn't support critical thinking as much. You just have to learn that and solve the formula … also the syllabus is so huge you've not time to apply critical thinking questions.*
(SS06_M_Greece)

One participant (SS12_M_UK) a mature student mentioned his previous schooling and critical thinking experience as quite boring, however he expressed it would have been different now.

Example:

i. *For me it wasn't that great (laughs), mine was more of sit down and listen, it was sort of quite a while ago. Now things has changed quite a lot, students now had different education and ideas, and they've more options to choose for their GCSE. I think some of them on the course have done GCSE in Astronomy, I think I've never had that options when I was in school (laughs) … I didn't enjoy learning, a lot of it was boring, it might be the slow pace it was going, especially the science subjects. I picked up quite easily, when everyone else was quite slow on it's a lot of the time, I was waiting for everyone else (laughs), Yeah. Everyone was taught the same way, it's a mess (laughs), I hope it's changed a lot.*
(SS12_M_UK)

When asked about critical thinking experience in previous schooling one participant (SS02_M_Libya) mentioned he had no idea what critical thinking is and he only heard about it when he came to the UK to study.

Example:

i. *In my high school I don't think you had any idea about critical thinking. The school doesn't teach us, just teach you a specific way of solving thing, so yeah, it doesn't encourage you to think independently, just makes you to stick to the teacher and write what on the board. May be some of them like encourage you, but overall I wouldn't say we had gain some knowledge or be aware of*

critical thinking skills in my country … Personally yeah, I think I learn critical thinking may be from here.
(SS02_M_Libya)

Critical Thinking Experience with Family

Participants experience with critical thinking also coded when they expressed their families' influence in encouraging them to be critical. Five from the ten participants interviewed mentioned the role of their family in encouraging them to be critical more than their schools.

Examples:

i. *I think it got more to do about the family environment than the rest of the society because the society you interpret based on the logics that you got it from your family.*
(SS06_M_Greece)

ii. *My dad always thinks through things to absolute max before he does anything, like he'll read an instruction booklet five times over before he puts things together a pack of shelves. (laughs) So, I think maybe I caught a little bit of that where I want to fully-understand something before I sort of embark on it, and I think that's sort of skills that I brought with me to here … so, I say that's from my culture, it's like watching my dad … inherited that streak! (laughs).*
(SS11_F_UK)

iii. *I think the only reason, if I am a good critical thinker is just the way that I think I got it from my dad.*
(SS13_M_USA)

iv. *In my family yes, but I can't say the same thing this for my own culture … but in my family they always encourage me to think about the weaknesses, critic something in order to get good results.*
(SS09_M_Cyprus)

v. *I was aware that I was taught differently to general consensus, don't know what it is. Yeah, I was very much aware of that, my Mum will influence me very much to think, you know to not care what are other people thought and generally take a different line. I still sort of have an underdog complex (laughs) … lots of times it gets me into arguments, but it helps with critical thinking … I think I was the smartest that I ever was when I was in primary school (laughs). That's because I took more*

interest at early age sort of interested in Science and <u>my grandma</u> sort of buy for me books about science and it was great, it was really fun.
(SS10_M_UK)

Critical Thinking Experience in Foundation Year (FY)

Participants' critical thinking experience in FY is coded when participants expressed their FY experience and critical thinking skills. Three participants mentioned critical thinking experience in FY and expressed that they are more aware of their learning and the importance of critical thinking skills in their FY now when they are in their first year of engineering undergraduate programme. Participants mentioned their experience in learning and applying critical thinking skills with examples of modules in their FY programme.

Examples:

i. *SS02* *I think I have some skills (laughs)… in <u>mathematics</u>, sometimes the module or our syllabus makes you think in a specific way and solve it in a specific way. But, I think mathematics could be, it depends how you approach a problem there isn't like a single way. So, sometimes you go around from a different way and I go to the lecturer and ask her, 'is that right?', she tells me, 'yeah that's right'. You can't just like disagree just because it's not her method … but, in <u>my country it's just you do it straight away.</u>*

I *So, how do you find yourself now?*

SS02 *I enjoyed it. I can, I gained more knowledge and made me think like I can do that, apply that on all topics not just a single topic. I can think about it in a different way. It's not like, if I get stuck on the way the lecturer explained it, I can just think it by my way, ask some others. (laughs) … that's interesting, Yeah … it encourages me think deeply independently, but I shouldn't stick to the lecturer. I can come up with my way of solving the problems … I've done that in EP as well … It was, 'vibration', I guess, yes. 'Vibration', in one occasion this year there were some, the lecturer gave us a question … I think that's an achievement.*
(SS02_M_Libya)

ii. *We sort of have lab report writing and essay writing, I've <u>used pretty much the basic same structure that I learnt in my foundation year to do now</u> … I'm more of an <u>independent learner</u>, or may be prioritise work than before … more fun (laughs) … I think the <u>critical thinking skills we're very equipped with them</u>. Like <u>the skills that we've learnt last year have helped me this year</u>. It helped me a lot, sort of figuring out and trying to piece information together. If I'm trying to learn something,*

say I've missed a week of lectures…are we reading from lecture seven and then, oh! I had to go back and understand this and to link it together like quite critical thinking.
(SS11_F_UK)

iii. *You can learn critical thinking in foundation year… at the moment in the United Kingdom I have more practical tasks than my country. In my country everything is based on the books and talking, all my teachers talk about the thing blah! Blah! Blah! Oh! I hated my previous education life in Cyprus, I hate it and I don't even want to think about it. Here we have more practical sessions and I hope we have much more next year.*
(SS09_M_Cyprus)

One participant (SS12_M_UK) mentioned his understanding of critical thinking in his foundation year has made him more aware of the importance of paying attention to details in an engineering context. His experience with critical thinking is coded when he explained using a scientific mistake which was made in designing a telescope.

Example:

i. *Lots of things require paying attention to details, there's lot of thinking involve in engineering (laughs)… paying attention to details, for example telescope, there was a mess up on one of the lenses when they were working around the world. You hope everyone is working on metres and centimetres, but when the American was doing their work they didn't realise they were working in feet and inches, and they ended up making a big mistake. When they launched and look through it, it was all blurry and they realised their mistake was someone didn't pay attention to the unit. Small detail had a big disaster. They had to correct and make a new lens and take another lens on it to fix the problem … when you read about telescope, certain stories that come up that this mistake was made, this sort of passed down to Scientist and things to explain sort of what went wrong in small details … all sorts of details.*
(SS10_M_UK)

5.10.5 Assessment Category

Assessment category was used to find out participants' views on assessing students' critical thinking skills in their engineering studies. It was noted participants responded to *Assessment* together with *Practice* category.

Coding system for *Assessment* Category

(i) Sense of importance
(ii) Sense of disagreement

Sense of importance

Majority of the participants agreed critical thinking skills are important in the FY and their engineering studies, however they disagreed that the skills are tested formally as a separate assessment. Only three participants from the ten interviewed agreed that critical thinking skills need to be tested as a separate assessment. Sense of importance is coded when participants make positive comments and mentioned that they will benefit from being tested on the skills.

Examples:

i. *Yes, I extremely agree because at this moment you are trying to learn vocation, a job, but if you graduate from the faculty of engineering without critical thinking it will be a shame for the university, every universities … I would like to be assessed I want to learn what is my weaknesses. (SS09_M_Cyprus)*

ii. *I*   *So, in your opinion do you think, because from the beginning you mentioned critical skills are important for engineering?*

SS08   *Yeah*

I   *So, on that basis what would be the effective way to assess students' critical thinking skills, do you think? Do you think it's necessary to assess students' critical thinking skills for engineering?*

SS08   *It would be good even just for self-assessment purposes would be good because it kind of shows like how you would be able to cope with actual real life problems later on because that's what actual engineers will deal with, real life problems.*

I   *So, this self-assessment do you think you would have benefitted if you was given to you when you were in the foundation year?*

SS08   *In a way, yeah. Almost any feedback is useful.*

(SS08_M_Latvia)

Sense of disagreement

Sense of disagreement is coded when participants were asked to respond whether it is important to test students on critical thinking skills for engineering. Seven from ten participants interviewed expressed disagreement in assessing students on critical thinking skills for engineering studies defending that critical thinking skills are already embedded in the engineering studies and exams.

Examples:

i. I *Do you think students need to be assessed because it's important and to find out if they've actually got it before they graduate?*

SS01 *Isn't that, aren't they in a way are already been assessed through exams and tests and course works? Isn't that already testing their critical thinking? For example, someone is not doing too well or doesn't know how to attack certain questions he would approach the professor and professor will show him the ways to attack the questions, therefore improving critical thinking. So, I would say they always been assessed when come to exams and stuff. So, I think there's no need to assess them explicitly.*

I *So, what you're trying to say is that learning of the skills is like an on-going process?*

SS01 *Yes, exactly … It just happens spontaneously while you're working on the questions, you simultaneously without you realising you're improving on your critical thinking.*

I *Umm, okay. But, do you think students will benefit if there's sort of an assessment?*

SS01 *Umm, personally, no I wouldn't*

I *You wouldn't?*

SS01 *I wouldn't, because I used to have my own ways of attacking tasks and problems and if I'm assessed based on certain guidelines or marked schemes then I don't, personally I don't think I would perform well.*

(SS01_M_Bahrain)

ii. *I don't think they should be assessed more explicitly, because after that it's just memorising, if they ask you what critical thinking skills are, that's just getting memorising losing the point of critical thinking.*

(SS06_M_Greece)

iii. *The test is to link to what you've already learn, so I do think they're kind of test it … but I think a test of its own, I'm not sure how well it could test you.*

(SS11_F_UK)

iv. *I was thinking that whenever you have a test it's somehow, kind of like changes the meaning of the learning process. I don't know it makes it weird. It makes like it's no longer about learning … My thinking is that this assessment is more about me like a child trying to get approval from my parents. I just say whatever I want to say during the assessment to get their approval and if you draw that out from that extreme … develop behaviours like survival mechanism in order to get what I needed to get positive reinforcement … so during exam I will learn what gets me a mark … it kind of feels like*

you're putting up a show when you're taking an exam … I know we need standards as a prove learning has occurred … I just hate it!
(SS13_M_USA)

Most of the participants who disagreed critical thinking needs to be assessed were noted to be uncertain and mentioned self-interest could improve critical thinking and others mentioned critical thinking skills' development takes place simultaneously with practice.

5.10.6 Language Category

Analysis on the Stage Three interview shows that participants' perception on language varied from linguistics traditional views of language as speaking, reading and writing to language as numerical language and computer codes in engineering context. All references to critical thinking skills with English and first language were coded as *Language* categories.

Coding system for *Language* Category

(i) English Language
(ii) First language
(iii) Maths and Computer Codes

English Language

English Language was coded when participants mentioned academic language, communication language, speaking, reading, writing, studying in the UK and English as a native language and its influence in critical thinking skills.

Almost all participants agreed that English language as academic language does play a role in learning and applying critical thinking in engineering and studying in the UK context. However, seven participants from the ten interviewed mentioned that they do not need a good command of English to learn and apply the critical thinking skills for engineering. Whereas, three participants (SS01_M_Bahrain), (SS07_M_Poland) and (SS09_M_Cyprus) mentioned a good grasp of English Language is important to learn and acquire critical thinking skills for engineering.

Examples:

i. *Critical thinking I think can make academic English much easier, for example when I came here I've no clue about the terminologies in Maths and Physics not even in my language but after one month I was acquainted with everything. I think the more you can apply critical thinking skills, the faster that you're gonna acquainted with academic English and the terminologies … It's true you have to understand the words, I do it even now. If I don't understand it I google the translation … but the only*

way not knowing perfect academic English can affect your skills, it delays you in applying them, but, if you have the skills, you eventually are going to find the way out.
(SS06_M_Greece)

ii. *SS08 If it's me it's definitely not critical at all, but it kind of impede my results slightly*
I How?
SS08 Well, for example, let's say you doing something practical which is part of your course because there're some practical parts in your course.
I Umm, what subject is this?
SS08 In general for engineering?
I Yeah.
SS08 In designing project, to be able to understand everything is really important than having this language barrier.
I What will happen if you lack language skills for this kind of practical work?
SS08 it's slightly annoying because it slows down the process, it impedes your progress, like for example in group work let's say you had to do this or this in a specific time frame. Let's say somebody gets sick or others or there's a problem or something like that. You have to do on your own or you have to like give instructions to somebody to do this or that, and if you have communication problem then it's just (_).
(SS08_M_Latvia)

iii. *I'm quite bias because I'm a native speaker of English, so, I never like had any language barriers to overcome to start learning all those skills … but, published piece of work it's written in such way that's different to how you speak. So, understanding that kind of language is important … I suppose struggle sometimes if there's proper piece of study or something that you've not background reading some information on. So, when I find like a web paper (laughs), you have to first understand the language and understand the difficult words they're using and then understand the content … I find if I don't understand a sentence I try to read the whole text and like figure it out where they're coming from and what they're trying to say. But, if you don't understand it any of it you can't really go on with critical thinking skills because you're stuck at that stage.*
(SS11_F_UK)

Three participants (SS07_M_Poland), (SS09_M_Cyprus) and (SS01_M_Bahrain) when asked about the role of English in learning and applying critical thinking skills in their engineering studies mentioned English is important to learn and acquire critical thinking skills.

Examples:

i. *English yeah, I think here they're understanding of critical thinking and they're comprehending it is more in my opinion based on the strengths in the English language because the stronger you are in English if it's a second language … you can translate back into your own language.*
(SS01_M_Bahrain

ii. *If you can understand what is written and it's written in English you can improve whatever it is. If I don't understand a question, whether it is, I don't know maths problem or a physic problem, or engineering problem I would not solve it. I first have to process the question from English into some whatever presentation I have it in my mind, mathematical whatever it is, and then do it. So, I have to understand English and it's important, especially the terminologies, behind the words, I don't know some variables, you know. For example, equal you need to know what equal means, one thing is same as the other. To know equal is something like that, one this is the other, so, you need to understand the meaning of the word, so, yes knowing the language is very important (laughs).*
(SS07_M_Poland)

iii. *Engineering require communication skills so, good level of English is a must … good level of English is important for critical thinking because sometimes you would like to enter in details. If you can't communicate properly…you could hide or fly, if you have good communication in English you will fly (laughs).*
(SS09_M_Cyprus)

Although nine participants from ten participants agreed English does help in learning and acquiring critical thinking skills for engineering one participant (SS02_M_Libya) expressed that good command of English is not necessary to learn and acquire critical thinking skills.

Example:

i. *I* — *Do you think students need good command of English to learn critical thinking skills?*

SS02 — *No, it doesn't require, you don't have to be good in English, like some native people failed last year, like some international students pass with very high grades. So, it seems like they'll manage to go through the topics without having to go through difficulties. Because, engineering is about numbers, diagrams, and sometimes, yeah, we need English. Some specific level of English like you can understand the lecturer, but you no need to be really good at English … Sometimes you can get away with it by translating some words, you google (laughs) of something … you can improve here, so I don't think you need good English, it's gonna improve by the time. The more you*

study, the more you get better on reading, you come across new vocabulary and new phrases.
SS02_M_Libya)

English language is also coded when participants responded to their experience as native speakers of the language. Three from the four participants interviewed expressed being native speaker of English and American English does not add any advantage to them in dealing with academic reading, writing and engineering studies in English.

Examples:

i. *I think as education as I moved up I went from senior school to different college to university, at every stage they require something different from you like written … like when I joined college, I couldn't write my exam it the same way as I did it in school. So, kind of have to learn like it is critical thinking skills like you have to learn how they want you to give answers and to write essays and things, and that's different to uni again. You see that it's not the knowledge that changed but the actual way they want you to present it's like lab reports are lot different to GCSEs to now … it's the approach that has changed…so I kind of sort write long worded answers in a quite a professional way. I think if I hadn't learn English to a higher level might not be able to sort of express myself in quite professional way because you do say things differently.*
(SS11_F_UK)

ii. *I* *How about report writing?*
SS12 *But, it's harder to write a report.*
I *Why?*
SS12 *It takes longer for me to construct sentences. So, I sort of can't write essays or paragraphs in a critical way. I sort of write it the note version of it, points that I want to say, and sort of construct those into paragraphs so, it does take a bit longer.*
I *So, it takes longer to write an essay, is it because of the thinking process or the language?*
SS12 *Sort of thinking and the language. English is not my best subject. So, I just want to sound right and make sure I put in the right grammar and everything else that's needed.*
I *You mentioned about the notes, do you find it difficult to expand the notes, like make it longer?*
SS12 *Occasionally, yes*
I *Why?*

SS12 Because, trying to explain what I mean is quite complicated, sometimes I can't find the right words or I end up writing sentences I can't finish, that doesn't make sense.

(SS12_M_UK)

iii. *I'm great, I'm fine with words, you know. I find that I'm better at writing e-mails than most of the foreigners at least, the people who aren't, didn't study English, natives. But, I'm finding the people who do really well they're from everywhere, and they not necessarily speak very well, and they did fine … The language is not doing me any favours, it's not helping me … I think lot more the locals who are failing or leaving … I think in American English, and I still don't understand even lots of the words, you know in the problems, the word problems. It must have been really hard for the French or the Greeks … it just words like explaining a cylinder or a thing, you know that you understand. This is a car or this a wheel or something hanging from a pulley, they assume and sometimes they used the words you know like they use it you still don't know. I used to be really good at like being able to find the context in like a question in being able like know where the question, what's it suggesting but it doesn't work. Maybe test questions are lot better now … but I can't guess multiple guess anymore and get the right answer. I can't guess like the context of the words anymore, so I don't have that advantage.*

(SS13_M_USA)

First Language

First Language is coded when participants responded to questions on whether their first language affects their ability to learn and acquire critical thinking skills in their engineering studies. Four participants expressed that their first language does affect their ability to use critical thinking skills.

Examples:

i. *I think it does affect, of course. I would say it depends on where you're come from. What your background is … I think I learn critical thinking maybe from here I first time heard critical thinking, even if I translate it and ask any speakers of Arabic they would say, oh, I don't know that, unless they study abroad they might say, yeah that's critical thinking.*

(SS02_M_Libya)

ii. *Of course, it affects. My mother tongue is Polish, and I came study in the UK, so, I have to adapt to be able to understand English. So, in my country, in my school I was doing everything in Polish, now I'm in the UK and everything is in English. So, once I came here I was struggling with English. So, I didn't fully understand questions, I didn't understand what they mean by some words or something, so I couldn't. I just like thinking, process of critical thinking wasn't very affected … I would do it if I*

know what it is. But, because I didn't know the English it was hard for me. So, like the results was affected I would say. I couldn't get the solution right.
(SS07_M_Poland)

iii. *I take it for granted that I can understand lots of the terminologies and stuff, when come to using like new words, basically. Engineering words like long ones which is difficult and stuff I find that, if that were to influence my critical thinking that wouldn't be a problem because I'm fine with picking up new words, English is obviously is my first language. So, may be it had helped me having English as a first language … again, this is something I can't tell because I'm English.*
(SS10_M_UK)

One participant (SS06_M_Greece), agreed his first language affect the learning of critical thinking, but in a positive way.

Example:

i. *Because, it's Greek. There's so many technical terms that I wouldn't know in English … I know them just because they are Greek words. So, I know what they mean … but, at the end of the day being a foreigner can help anyway, because, if you know a word both in English and your language you have an extra clue what it could mean. So, I don't know because it's Greek generally (laughs), because as foreigner it helps to have a second idea of what that means.*
(SS06_M_Greece)

However, one participant (SS10_M_UK) expressed his views as a native speaker based on non-native perspectives.

Example:

i. *I think it probably does depend on the student and the language of their native country they're from, some a lot easier to translate to their own language … I've friend from Germany and was able to pick English easily, a lot easier say someone from China. I think it's just the way some languages are, most of the European languages are similar, but again, like Chinese they have completely different structure to language and it's not easy. I think they might carry a similar things like French, they have sort of different ways of saying words of masculine and feminine that doesn't seem to exist in*

English … all the people who've done group work with me tend to be from a similar background like UK and not far away.
(SS12_M_UK)

Mathematics and Computer Codes

Language is also perceived as language in an engineering context by participants. *Maths* and *Computer Codes* were coded when participants mentioned maths is a visual form of language which is represented in a different way to other forms of language like the spoken language.

Example:

i. *I think language it is critical thinking it's just sort of manifested as a language so, where maths is clearly which very quantifiable way of critical thinking, code is just represent that, it's just that maths is more of a visual way, and spoken language, and I think critical thinking is just applied in a different way. It's way you could express critical thought, I think*
(SS10_M_UK)

5.10.7 Practice Category

Practice referred to the type of practical exercises that participants had to learn and develop critical thinking skills in their FY and the types of practice they preferred in the FY in general to practise effectively the skills. Stage Three interview analysis shows that participants linked engineering modules like Maths, Computer Programming, and Electronics and Electricity as examples to explain their experience in practising their critical thinking skills. Apart from the engineering modules, participants mentioned group work and group project to relate *Practice* and critical thinking experiences in the FY programme. *Practice* is coded when participants mentioned modules, group work, using questions, experiment module outline and boring.

Coding system for *Practice* Category

(i) Modules
(ii) Group work and Group project
(iii) Questions
(iv) Experiment
(v) Module outline
(vi) Boring

Modules

The analysis of the interview data shows that participants used examples of FY modules to explain their experience practising critical thinking skills and how these modules could be used to practise the skills. The modules with the most practical skills mentioned by participants were Maths, Computer Programming, and Electronics and Electricity.

Examples:

i. *In terms of critical thinking I would say that the most important thing is language and in every sense that you can mean language … in term of engineering the language is Maths and also code, so what you really have to learn is how to be fluent in Maths and be fluent in code. If you could do those, there's no strict solutions, well there are obviously, but there are no strict applications. They work for anything, that's the beauty of language. You know, I will use the same Maths in trying to explain how gravity works that I used to explain all sorts of simple things like you know, 'stress,' and, 'strain', that kinds of stuff. So, I think to become fluent in the languages, and now I can represent what I do mathematically using code, you know that sort of thing. So, I think by learning those that's the best way to learn critical thinking.*
(SS10_M_UK)

ii. *In mathematics, sometimes the module or our syllabus makes you think in a specific way and solve it in a specific way. But, I think mathematics could be, it depends how you approach a problem there isn't like a single way … you can go about it in a different way. It's not this is specific way. Maybe there is a rule and it's called 'product rule', but you can change it to, 'quotient rule', just by putting the 'denominator', down it becomes, 'quotient', suddenly. So, you can deal with it you deal with the number to the power of minus one instead of (laughs) I don't know … you can manipulate the rule.*
(SS02_M_Libya)

iii. *In programming they did have, Yeah, there were some stuff that themed with design a project because in the first year I think. I also had a similar project but completely in a different subject. But I think, the way of think and work ethics applied to that partially transferred to design which is completely a different subject to programming. But, I really thinking of it really into that because like sure, when you let's say making let's say a piece of software.*
(SS08_M_Lativa)

iv. *Foundation Year definitely useful, but it can improved may be in specific aspects like, may be specifically like programming content slightly, that's a very specific thing. Although, Electronics I think it also quite well improve your critical thinking skills, since Electronics is the most challenging thing in the foundation year.*
(SS08_M_Latvia)

Group Work and Group Project

Group Work and Group Project was coded when participants mentioned their experience in gaining critical thinking skills through group interaction and listening to different viewpoints to solve problems. One participant (SS07_M_Poland) mentioned group assignment provided practice to apply knowledge of theory to solve problems.

Examples:

i. *We worked in computer apps groups, we worked in groups to generate a software program to help, it meant to help the new computer students of foundation year of the following year, helped to make specific topic like, 'vibrations', 'velocity', the topic that you choose, year. We split the work to four or three depends on group members and we have to do like slides work on power points and deliver it every two weeks to deliver some works. On some stage we got stuck and try to ask and meet together, and that gain you some skills when everyone say his point of view. Yeah, this is how I apply it and gain some skills last year working in groups.*
(SS02_M_Libya)

ii. *The fact that you're doing theory, you learn theory that does not mean you're actually able to do something. This is same with engineering. Okay, I have learnt some theories I know some concepts but do I actually know how to apply these concepts and solve problems? No, I don't know until I actually did the problem, so, the critical thinking is actually getting the practical things.*
(SS07_M_Poland)

Questions

Questions is coded in Practice category when participants were asked to respond to what are the effective ways to develop critical thinking skills in FY programme. Three from the ten participants interviewed mentioned that using questions in lectures and modelling the problem solving methods by lecturers could be the effective way to practise critical thinking skills.

Examples:

i. *Maybe they give question and go through the solution. How to do it, and how to approach it … like watch someone do it … I think most engineering problem … So, once you learn the techniques to one kind of questions, you can apply to every questions like that … I don't really learn much by listening to someone talking for forty minutes. It's quite nice in the lectures to go through a problem together and then if you can't work it out immediately ask to find out why, and rather than try to absorb lots of information for forty minutes and go home try a questions but not a clue on how to approach it.*

Like you may have a list of facts but that won't help you to answer the problem…I think if a lecturer runs through one or two problems it helps a lot.
(SS11_F_UK)

ii. *Maybe they should teach you the basic, like how you should use it, but they shouldn't tell you, 'oh! You should do it like that', gives you, 'food for thought' … Because, if they did not dictate how to do it, but taught just some basic features what critical thinking includes. May not explicitly … may be through questions … for some reasons I like the maths technique … while at many times when I'm doing critical thinking of my own I went back to lecture slides … I connect it to some tasks and use it in my critical thinking process.*
(SS06_M_Greece)

iii. *They did a great job of facilitating questions, so there was tutorial and stuff, where we set questions by weekly basis, I think, whole bunch of questions. I was for every modules, though there're slightly less for some of them, but every modules have regular questions, and that was great. And, they also gave tutorial sessions where you can go through the questions with the teacher when you don't understand something. So yeah, that was great, and they did a great job for that.*
(SS10_M_UK)

Experiment

Participants also mentioned *Practical Experiment* when asked about the effective ways of teaching to develop critical thinking skills in the FY programme. One participant who had hearing impairment mentioned he preferred the lecturer conducts practical experiment in the lectures.

Example:

i. *My lecturer carry out a full experiment first … first practical experiment, discussion then theoretical information would be best for me.*
(SS09_M_UK)

Module Outline

A participant expressed the importance of informing students about the critical skills they are expected to learn in the FY programme. The participant mentioned that knowing the types of critical skills will help him to develop the skills. The participant also mentioned that critical skills are employability skill, therefore the skills need to be mentioned in the *Module Outline* for students to know.

Example:

i. SS12 *I think it's probably more important to highlight in the course these critical skills, cause during the entire foundation year we've been taught stuff but we didn't realise. Well some of us, they're trying to teach us critical skills but, they must actually tell what sorts of skills that we'll be developing during the course and where they apply to.*

I *Right, so do you prefer this to be explicitly stated in the module outline itself?*

SS12 *Probably sort of more of an outline. Yeah, say, it's been taught in the lectures. It's hard enough to fit everything in, but if it's there, something quite important, and if you don't know about them, and how you suppose to develop skills you don't know about or you don't know whether you're lacking in more skills you have, critical skills, the more successful you're going to be, I think (laughs). I think they've tried a lot of things in life, but if people don't know about them then, it's a shame (laughs) if you start of not knowing many critical skills and you compare in further education you can learn more. It feel you've never learnt anything but certain skills help to structure your CV because employers are looking for critical skills, so if you know of them you can give examples and you stand out.*
(SS12_M_UK)

Boring

Boring is coded in the *Practice* category when participants were asked whether they had sufficient practice in critical thinking skills in their FY. Although almost all participants mentioned they had sufficient practice in critical thinking skills one participant (SS13_M_USA) a mature student expressed that the learning condition is more towards rote learning and learning does not happen in the class.

Example:

i. *Maybe everything is not the way we think it is, I don't know. I'm not saying what been taught is right, it's just that, maybe it's boring, too boring the way it is right now…it feels like it's all rote, it's all, it's formula … I'm not a teacher, I know you gonna cram all these materials and do in certain time, you know I try sitting in front that works sometimes. But even then, it's just like you know either your*

mind wander, I'm just trying to stay awake … I'm just trying to pay attention and take notes, but learning does not happen in the lectures, and I know how the system is built.
(SS13_M_USA)

5.10.8 Culture Category

Participants' critical thinking and learning experience in general and in the UK in particular is analysed in Culture category. Participants mentioned academic culture, British culture and Turkish culture when explaining their learning and critical thinking experience.

Coding system for *Culture* Category

(i) Academic culture
(ii) Turkish culture
(iii) British culture

Academic Culture

Academic culture is coded when participants were asked whether students' first language affects their ability to learn and acquire critical thinking skills. From the ten participants interviewed one participant mentioned academic culture to explain that studying in the UK academic culture strengthens students' command of English.

Example:

i. *So, I think critical thinking is for me depends on more on your strength in the English language … especially here, in this country in the culture we're in, I would say it strengthen their English language.*
(SS01_M_Bahrain)

5.11 Summary – Stage Three

Stage Three interview analysis shows *Knowledge* and *Attitude* on critical thinking skills are predominant categories for all participants similar to Stage One interview. Participants' responses to the *Knowledge* category clearly show that participants were more focused and clear about their understanding on critical thinking skills for engineering studies. This was obvious when participants attempted to define critical thinking skills using their learning experiences in critical thinking skills and applying them in their engineering modules in their completed FY programme. Participants also included more details in their definition of critical thinking skills in which clearly they have better understanding and have developed some of the important critical thinking skills for engineering foundation and undergraduate studies. Almost all participants defined critical thinking skills for engineering as *problem solving* skills as major skills, while two of the ten participants interviewed defined critical skills as *picking up the truth* which was more philosophical and scientific.

Stage Three interview analysis also noted that participants interpreted process involved in critical thinking skills as part of critical thinking skills, for example *considering point of views*, *learning how to learn and think*, and *sourcing*. Participants also used terms like *independent thinking* and *life skill* as critical thinking skills. Participants' definition of critical thinking in Stage Three, which was the final interview after a year observation shows participants have moved from specific approach to learning and applying critical thinking skills to more pragmatic approach to critical thinking skills as mentioned by one of the participants (SS10_M_UK). He explained, that his approach to critical thinking has changed from just focused on maths and coding skills in engineering to creating his own scenarios and formulating his own questions to solve problems. This could be the outcome of the foundation year programme, which provided opportunities for students to familiarise the basic level of engineering and as they progress to be more independent on their problem solving skills.

Attitude category has seen some changes in the ways participants respond to critical thinking skills and engineering as compared to Stage One and Stage Three interview, where there were some uncertainties about the importance of critical thinking skills in the FY in Stage One. Almost all participants expressed the importance of critical thinking and their foundation year for their studies now, and this was noted when participants gave positive comments on foundation year and their experience in critical thinking skills. However, two participants (SS06_M_Greece) and (SS13_M_USA) expressed their frustration of their experience in learning and applying critical thinking skills in their studies. The two participants also mentioned that they did not do well in the exam. They were either repeating some of the modules or repeating the FY programme, and this could be the reason for their frustration and attitudes towards critical thinking skills. As for the rest of the participants, it is quite clear that they have adopted a more positive attitude towards critical thinking and its importance to their engineering studies.

The analysis of Stage Three interview about participants' learning experience has shifted from Previous Learning experiences in Stage One interview to *Critical Thinking Experience* category in Stage Three interview. *Critical Thinking Experience* category used *critical thinking in school*, *critical thinking with family* and *critical thinking in FY* to analyse this category. In the Critical *Thinking Experience in School* only one participant (SS01_M_Bahrain) confidently said that he had critical thinking experience in school which he claimed as a result of him studying at an international school with British syllabus and in Bahrain and Dubai which do not practise conservative education system. Nine of the ten participants interviewed expressed that they either did not have sufficient practice or have not been exposed to critical thinking skills until their FY study.

Stage Three data clearly shows participants learning experience in school was more exam-oriented than teaching and learning academic skills like the critical thinking skills. The findings were quite surprising, for the research hypothesised that participants who studied in western education system have more exposure to critical thinking skills due to critical thinking culture having connected history which largely belongs to Europe as compared to other types of education system. However, it was a different case in Critical Thinking Experience with family where almost all participants claimed that their family have more influence in their thinking than their schools, teachers or their education system. The critical thinking experience in FY on the other hand, shows almost all participants have learnt and applied their critical thinking skills in one way or another in their studies. This was apparent when participants were able to provide examples from their FY and claimed they were more aware of critical thinking skills now as compared to when they first started their engineering foundation year.

The research hypothesised that *language* could have a more pertinent role in participants' learning and acquiring critical thinking skills in the Stage Three data. The data shows some shift in participants' perception in *English* and its role as an academic language in their engineering study as important. However, the data shows participants do not regard a good command of English as vital in learning and applying critical thinking skills, but claimed it only delays the process of solving a problem or completing a task if they are not competent in the language. In contrast, three participants, (SS07_M_Poland), (SS09_M_Cyprus) and (SS01_M_Bahrain) expressed that a strong grasp of English is important to learn and apply the skills. For Language category, native participants use it to describe their experience as native speakers. Data from three native participants from the four who participated shows they also find English as academic language quite challenging as it is to the non-native students. Four from ten participants find their *first language* does affect their ability to learn and apply critical thinking skills. The rest find they could cope with their engineering studies and claimed that major part of engineering is largely numbers, diagrams and codes. *Maths and codes* as language was the least mentioned in Stage Three compared to Stage One interview.

Practice is another predominant category for all participants in the Stage Three interview. In the Practice category participants clearly showed their understanding and application of critical thinking skills which were explained in detail with examples from engineering modules, group work, the importance of formulating questions, the effective ways to teach critical thinking based on their FY experience.

Culture categories clearly show participants were able to use both general and specific examples to relate their academic and cultural experiences. The Stage Three data analysis shows Culture is least mentioned by participants unless raised by the researcher as the interviewer.

The Stage Three analysis shows the use of *Assessment* categories to find out participants' views on whether assessing critical thinking skills for engineering is necessary. The data clearly shows participants acknowledged the importance of critical thinking for engineering but disagreed it needed to be assessed. However, the data also shows participants were aware of the benefit of testing critical thinking skills as self-assessment and as motivation to learn the skills.

A sample Stage Three interview data is given in (*Appendix I.3 on p 318-325*).

5.12 Conclusion

Overall, the Stage One, Stage Two and Stage Three interview data has illuminated some useful insights into students' perceptions and attitudes towards critical thinking which could help to understand students' learning needs in the FY in general and developing the skills in particular. The data could also help in designing innovative course design which is more student centred for FY based on types of students, for example, young and mature students, or students with special needs in learning and developing critical thinking skills for engineering.

Chapter 6 Findings: Module Instructor's Interview Report

6.1 Interview Report

This chapter presents analysis of qualitative interview data, which explored module instructors' conception of Critical Thinking skills (CTs) for engineering and their views on how Engineering Foundation Year (EFY) students learn and develop their critical thinking skills.

The module instructors were asked how they conceptualise CTs for engineering, and their pedagogical choices to provide opportunities for students to learn and practice critical thinking skills within the Foundation Year (FY) programme. They were also asked what the contributing factors were for students acquiring, and the barriers for not acquiring CTs in their foundation year. Module instructors were also asked to what extent English language and students' prior learning affect their ability to apply critical thinking skills in their foundation engineering study.

6.2 Interview Participants

The participating instructors were from two different universities which were University X and University Y in the UK. All of them taught on the foundation engineering programme during 2014-15. However, for University Y only the module instructors participated in the interviews, unlike University X where both module instructors and students participated in the interviews. Although University Y only had module instructors and not students as participants, it was decided to keep the University Y data as supporting data, because it had some emerging issues surrounding the topic discussed, which was not present in University X data.

Module instructors as interview participants were recruited by first sending a formal invitation via e-mail with a participant information sheet with an overview of the research, (*Appendix D on p 272*). Then, an appointment was arranged to explain about the research in person and to obtain their consent for the interview. Ten module tutors participated, eight of them from University X and two from University Y. Of the University X participants, six were from the Faculty of Engineering and two from the Faculty of Humanities. The two participants from University Y were from the Faculty of Engineering. Among the ten participants, eight were native speakers of English. Two were from overseas but both had been residing in the UK for more than twenty years. There was an equal balance between genders with five participants each. *Table 6:1* (*on p 152*) shows a summary of the participants.

Table 6:1 Participant Summary

Faculty/Discipline: Engineering and Humanities	**Instructors' identifiers and modules taught**	**Experience in FY**	**Gender**	**Native speaker**	**Code**
University X	MI01 – (MT) Maths A and B	13 years	Female	No	MI01_MT_F_NN_UX
University X	MI02 – (CW) Computer Application Course Work	3 years	Male	Yes	MI02_CW_M_N_UX
University X	MI03 – (WS) Workshop	20 years	Male	Yes	MI03_WS_M_N_UX
University X	MI04 – (EP) Engineering Principles	6 years	Female	No	MI04_EP_F_NN_UX
University X	MI05 – (MS) Mechanical Sciences	8 years	Male	Yes	MI05_MS_M_N_UX
University X (Humanities)	MI06 – (PWA) Language Pathway A	1 year	Female	Yes	MI06_PWA_F_N_UX
University X	MI07 – (EE) Electrical Electronics	7 years	Male	Yes	MI07_EE_M_N_UX
University X (Humanities)	MI08 – (EES) English for Scientists and Engineers	7 years	Female	Yes	MI08_EES_F_N_UX
University Y	MI09 – (MT) Maths	1 year	Female	Yes	MI09_MT_F_N_UY
University Y	MI10 – (ET) Electrical Technology	1 year	Male	Yes	MI10_ET_M_N_UY

The participant's identifying codes are composed as follows:

Participant ID non-native

Example: MI01_MT_F_NN_UX

module gender University X

6.3 Data Collection and Interview Procedure

The participants were interviewed on one occasion mostly in Semester Two (2014-15). However, one of the participants was then on maternity leave, so she was interviewed in Semester One (2015-16). The interviews were conducted face to face, and lasted between 30 and 50 minutes.

The module instructor's interview was designed to answer the following research questions:

2) How do students learn and develop their critical thinking skills in the Engineering Foundation Year (EFY)?
    a) To what extent do students have the opportunity to practise critical thinking skills in the engineering foundation year programme?
    b) What types of critical thinking skills are exposed to during the foundation year?
    c) To what extent does students' prior learning influence their ability to learn and apply the skills in their foundation engineering study?
3) What is faculty's (lecturers') goal for students' critical thinking skills?
    a) How do the foundation year module instructors define critical thinking skills and how does this influence their pedagogical choices?
5) To what extent does language play a role for students in learning and applying critical thinking skills?

An interview guide was used to elicit information from the research participants using semi-structured interview techniques, as in the student interviews, (*Appendix H.2 on p 281*).

6.3.1 Data collection and data preparation

All interviews were audio recorded, transcribed using verbatim transcription, coded and stored in accordance with research ethical guidelines.

6.4 Data Analysis

As with the student interviews, data analysis was conducted using a combination of deductive and inductive coding. The research questions were used as a starting point to identify the main categories and themes to analyse the data. The coding system was further developed based on recurring patterns of words and phrases, which clustered into themes to identify the main categories. The data was then manually coded based on words and phrases of similar meanings, using a set of main category codes and subcategories.

The following are the final main categories identified:

(i) Conception of Critical Thinking

(ii) Pedagogy

(iii) Practice

(iv) Language

(v) Maturity

(vi) Culture

As will be discussed below, the data analysis shows some obvious similarities in how participants conceptualised critical thinking skills except for one participant from the Faculty of Humanities. The similarities in their definition of critical thinking skills were largely influenced by participants' previous background in science and engineering.

In the participants' accounts, *Pedagogy* was often interconnected to content, knowledge and mathematical skills in engineering studies. *Pedagogy* was related to mode of teaching such as *lectures, interactive group work* and *one to one sessions*. *Pedagogy* was also noted to have direct connection to students' *Practice* of critical thinking skills using *worksheets, writing lab reports, writing reflective reports, presenting posters* and *Question and Answer sessions*. Practice was also related to *support class, workshops, group work* and *language games*.

Another main category is *Language,* which is related to English language as academic language and students' first or second language. Some other references were made to language as mathematical and coding language. *Language* was also noted to have close links to *Conception of Critical Thinking* and *Practice*.

Maturity is another main category, of concern to instructors, which arose in the interview analysis. The participants also discussed *Maturity* with reference to students' *Practice*.

Culture is another main category, which appeared in the analysis, but this rarely had close links to *Pedagogy, Practice* and *Language*.

Coding and symbols

The data analysis used codes and symbols to identify the participants and participants' reactions at the time of the interview. For example, (MI01_MT_F_NN_UX) is the first participant interviewed (MI01), who taught mathematics (MT), and the instructor is a female (F), a non-native (NN), and she is from University X (UX). As for the symbol, (_), in the transcription denotes pauses of more than 10 seconds, the thinking time taken by the participant to respond. The pauses occurred, when the participant either needed time to reflect, or uncertain about a concept of an issue raised in the interview. Besides that, (laughs) is recorded when the participant openly laughed at his/her uncertainties, or relating his/her classroom experience when discussing his/her view.

6.4.1 Conception of Critical Thinking Category

The analysis shows that almost all the participants showed some sort of uncertainty when asked to define critical thinking skills with a lot of long pauses and time taken by the participants for them to conceptualise critical thinking. However, when they responded they all drew upon their experience in science and engineering to define critical thinking skills except for one participant from the Faculty of Humanities with English language teaching experience who had a slightly different way of conceptualising critical thinking skills for foundation engineering.

In the *Conception of Critical Thinking* category *identifying problems and solutions* was the most mentioned by the participants in different contexts. *Mathematical thinking* is another interpretation of critical thinking commonly used by the participants. Some participants used expressions such as *creative and critical thinking*, *weighing different views*, *self-critical*, *asking questions, recognising own limitations*, *having a curious mind*, and *questioning authority* to conceptualise critical thinking, but these terms were used rarely, and among them only one participant included *noble* as part of critical thinking skills.

Coding system for Conception of Critical Thinking category:

(i) Identifying problems and solutions
(ii) Mathematical thinking
(iii) Self-critical
(iv) Having curious mind
(v) Realise limitations
(vi) Practical skills
(vii) Questioning authority
(viii) Asking questions
(ix) Creative and Critical thinking
(x) Weighing views

Identifying problems and solutions

Participants defined critical thinking as *identifying problems and solutions* by linking their answers to the modules that they were teaching. Examples given for the Engineering module were about solving Maths numerical problems and Physics theoretical problems. Participants also mentioned the importance of having a good grasp of subject knowledge to be able to apply the skills.

Examples:

i. *It's a skill. When you have a problem, probably the foundation year student when going into engineering you have a problem that is maybe not stated. Then, you need to think how to understand the problem. How to keep what is essential, and how then to translate that kind of abstract problem. Solve it, and then come back and present the solution to the person who asked you a question in a way that the person understands and can do something with it (MI01_MT_F_NN_UX)*

ii. *Identify the problem, define the problem, and examine the options, the actual plan and the consequences. (MI05_MS_M_N_UX)*

iii. *(_) They should have acquired a certain level of understanding of engineering and physical principles and they should be able to re-apply those to solving problems. (MI03_WS_M_N_UX)*

iv. *(_) Either to be able to think outside the box and being able to approach problem solving with variety of either strategies or perspectives with which trying to solve a problem … Yeah, either to think outside the box or the ability for example to apply scientific methods in a flexible way. (MI06_PWA_F_N_UX)*

v. *(_) I think it's ever-changing (laughs), sort of for engineers … the confidence to try and solve the problem, and to have an idea of what the answer should be … So, I mean if a student is doing a problem, and they come out with, you know, the length of a table is going to be 3 kilometres long, they put that as an answer not thinking a table 3 kilometres long doesn't sound right, and to think back and check. So, have an idea of what it means in the real world and that will be difficult to teach because that will need experience as well … like an idea that it takes 4 years to build (laughs). (MI09_MT_F_N_UY)*

The analysis shows a majority of the instructors define critical thinking as *problem solving* within the engineering context. (MI01_MT_F_NN_UX) claimed working in the engineering context involves problems, 'that may not be stated' therefore, students have to understand the problem, reformulate it, solve it, and communicate the solution with clarity to the person who asked the question, so that the person could make use of it in a productive way. This is further supported by (MI05_MS_M_N_UX), who defined critical thinking as *identifying the problem*, defining the problem, examining the alternatives, finding a solution and its consequences. (MI06_PWA_F_N_UX) explained that *problem solving*, flexibility and approaching the problem with different perspectives to solve a problem. However, (MI03_WS_M_N_UX) claimed that, for problem solving, students should have a certain level of understanding of engineering and physical principles to be able to apply that knowledge to find solutions. Besides that, for problem solving skills, (SS09_MT_F_N_UY) found that confidence is important in *identifying problems* and finding solutions.

The analysis though, shows that while a majority of the instructors are aware of the importance of problem solving as a critical thinking skill for foundation year (MI09_MT_F_N_UY) also commented on the learning process and the limitation of critical thinking possibilities for foundation students. This is because it takes experience to learn and acquire the skills as a continuous process and not as a final destination.

Mathematical thinking

Some participants from engineering used *Mathematical Thinking* to conceptualise critical thinking skills. One participant (MI05_MS_M_N_UX) perceived Maths as a subject, which inherits critical thinking skills, therefore, mathematical skills were equated to critical thinking skills.

Examples:

i. *MI01:* *So, for me critical thinking skill equals to thinking skill. I mean for me if you think then you think critically, I don't know (laughs)*

I: *Yeah, like thinking in what way? Like in a creative way, there aesthetics are involved as well.*

MI01: *Then, I would say <u>mathematical thinking</u>. So, you are given something and you know you have to use that to produce something else. So you know, and often you know what you are given and you know what you want to get. So, now it is that thinking process to connect that to find the way from one to the other. So, this is you know kind of, <u>first is to formulate</u>, to <u>have the statement you know</u>, so what you need in order to work to get (laughs), but, when you have that you know, you somehow have to see how you know <u>in a logical way</u> go from one to the other.*
(MI01_MT_F_NN_UX)

ii. *I assume, you see, I don't, though I'm sort of almost <u>equating critical thinking</u> <u>with mathematical skills</u> I don't quite entirely do that, but that is a chief element of critical thinking they need. It's <u>mathematical skill</u> ability to think logically, and I tend to see not everybody who starts the course has a reasonable ability to think critically. I'm clearly incorrect in this, but (laughs), we haven't really got time to teach critical thinking as such.*
(MI05_MS_M_N_UX)

Two participants, (MI05_MS_M_N_UX) and (MI01_MT_F_NN_UX) relate critical thinking to mathematical thinking similar to the problem solving skill that is to formulate and understand a statement in order to achieve a solution in a logical way. However, one participant (MI07_EE_M_N_UX) did not share the same view on Maths being always a critical thinking subject.

Example:

i. *You can argue that pure Mathematics doesn't require a lot of critical thinking, you can argue that but I'm not going to state that, because it could be possible because some people learn Mathematics by rote and they're just like riding a bike. You learn to ride a bike you're not analysing how to ride a bike once you know how to do it and you can argue that you know once you're a good mathematician then you are no longer thinking but that I'm just suggesting, I'm not saying that's true. But, something like my topic like EE you have to think a bit more because you have to understand the problem, even in MS as well and even in EP I would say as well. You have to understand the physics of what's going on and this unique scenario that is given in this question, is it going to slip or is it going to fall, you know, what's gonna happen and you know all the different parameters that you have to put them all together, so you have to think more critically. So, yeah, again what is better knowing, having lots of practice with problems or thinking critically I think we tried the last couple of years to make the exams more unique so they just can't do past exam papers and then get to this one as just a walk in the park. Particularly, last year we made a big effort to make things slightly different to make them to think a bit deeper and to struggle a bit more.*
(MI07_EE_M_N_UX)

Although, instructors' views support the importance of critical thinking, (MI05_MS_M_N_UX), however, admitted that they do not have the time to teach students critical thinking in such a way in the foundation year.

Being self-critical

One participant also used terms like being *Self-critical* and *Self-questioning* as critical thinking features. The first of these ideas was mentioned by an engineering participant with more than twenty years of experience in teaching and syllabus design for a foundation engineering programme. Being self-critical was also related to communication skills, the ability to communicate ideas and solutions to engineering problems to others, as an essential part of being an engineer.

Examples:

i. *I think you want the students to be thinking that they've got this broad approach to the problems. How do they tackle them? But, and also to go back, and become constructive in the way, that, to be critically constructive in the way they approach it and see, 'is there a way that I can do this better?', 'I'm spending an awful lot of time on this particular thing and I don't think I've done that, I've not done it productively'. So, analysing their working methods and being able to apply sort of some positive remedies to it I think is important. So, you cannot do that without being critical of what you're doing. I suppose, you know, you walk into a, every time you walk into a classroom,* *you walk out thinking, umm could I've done that better, what was the problem there, was I not prepared enough?', you know? Whatever reasons, you know, 'should have gone to bed at 10 o'clock last night instead of, whatever I think everybody is self-critical aren't they? (MI03_WS_M_N_UX)*

ii. *I think in terms of language there's the language of engineering and science, which they've got to master. They've also got to master their communication skills with other people, and so engineering is not just about the doing but it's about transmitting that knowledge and information. Unless you can be critical about what you're actually about the way you learn and the subject that you're taking in the wider sense, questioning results and questioning the ways you're doing things, then I don't think in the end you're not going to be good in communicating to other people. So, I think the critical skills part, is an essential part of being an engineer because other people will ask you the questions. So, if you try to ask yourself the same question first (laughs), so hope fully you've got the answers. So, I think it's an essential part in the learning process and in the transmission of that learning into practical activities and into communicating with other people. Perhaps engineers are not often best at communicating or scientists. (MI03_WS_M_N_UX)*

Being self-critical and self-questioning is described by (MI03_WS_M_N_UX) as one of the fundamental skills that engineering students must master, for engineering is not just about doing, but the ability to self-reflect, identify ones strengths and weaknesses is an essential part of the learning process. This skill gives clarity to one's understanding of a problem through self-questioning, which then can be conveyed to others in resolving a problem.

Having a curious mind

One participant defines critical thinking as having a *Curious Mind*. According to this participant, engineering students need to think constantly about how things work within the engineering setting, though for this students also need a good grasp of the subject matter.

Example:

i. *I think they always have to set their mind to think about how things work, that is important, they just don't accept it. Looking at engines, looking at gas, or diesel, you know how was pressure generated, how does light interact with surfaces? So, they have to have that curious mind to want to know these things. So, that's quite important and also they need to read a lot of books to understand the different systems, different terms, definitions of you know different, because we cover a very wide range of topics and physical mechanisms. If they don't have that background they would feel you*

know … coming from another very non engineering background find it hard to incorporate you know, comprehend the techniques, the terminologies.
(MI04_EP_F_NN_UX)

Having a curious mind is important to understand how things work in an engineering context. To have a curious mind does not only involve skills, but a wider knowledge about various topics and physical mechanisms to understand how engineering works. Though, (MI04_EP_F_NN_UX) describes the relevance of having an inquisitive mind, it is not clear whether the instructors believe that this aspect of critical thinking can be taught in the foundation year, or whether some students are inherently more curious than others.

Realise limitations

Another participant mentioned that students need to realise their own strengths and weaknesses, so as to identify what suits them best to survive the course.

Example:

i. *Sometimes, you have to accept that this is it, you can't do anymore of them. You've only got a certain amount of knowledge and you can't deal with it anymore without that extra in-put. So, sometimes you've got to accept, that this is the level that you're at, and you deal with it at that level at that moment in time … I think, well on the gender thing male students tend to be more confident, that they over estimate their ability, female students tend to, and this is a generalisation, underestimate their ability … so, I do think you have to be aware of your own limitations and whether mathematically or whatever, you know, and some of them do that in a sense perhaps with the maths. They may have come along and thought 'I want to do electronics' but they realised well this is a very mathematical subject, environmental engineering may be more in tune with their abilities, their natural abilities where they're good at communicating and in language and so on, but not so good on the nitty gritty details of the thing. So, I think, at the end of the foundation year this is why some of them change subjects because they realised the limitations of their, not that they've actually reached it but they know their strengths and they know their weaknesses and they can change course to try and make the best of what they're doing.*
(MI03_WS_M_N_UX)

Identifying one's own strengths and weaknesses, and realising his/her limitations is vital in decision making. (MI03_WS_M_N_UX) explained that, this skill helps in developing the critical being of a student in the foundation year programme in deciding their undergraduate destination engineering course. Nevertheless, how far this aspect of critical thinking is applicable in the foundation year engineering context is not clear, whether for making personal or engineering decisions.

Questioning authority

Critical thinking skills for engineering were also defined as *Questioning authority* by one participant, who used religion and his past personal experience as doctoral student to relate his definitions of logic and critical thinking.

Example:

i. *(_) I would say, it's difficult to sum up in a very short space of time, but essentially it's the ability to arrive at logical argument, another important part of critical thinking. I was brought up as a Catholic and even though I thought critically or thought logically about things, I started from the premise of what Catholic priest has told me (laughs) whether that it's true or not is by the bible. But, so part of the critical thinking is to question authority to some extent that's probably the part that we don't encourage. We tend to concentrate more on the ability to draw conclusions … because if they question everything I say I never get anything taught but, I would say critical thinking does involve that … but to some extent the facts are so well established there's almost, you can say they are established by experiment, you know. I mean the way science progresses is through questioning other people's work and not necessarily showing they are wrong, I mean Einstein didn't show Newton was wrong. Einstein showed that Newton was incomplete, I say it's a big difference … we don't encourage them to question authority and I think that applied for my degree as well that I wasn't encourage to question authority until I got to my PhD when I was encouraged to look at things from a different point of view totally different. But, I think you need some basic level of knowledge before you actually start to question authority.*
(MI05_MS_M_N_UX)

Commenting on *Questioning authority* as a critical thinking skill, (MI05_MS_M_N_UX), relates that questioning authority was not encouraged until he became a doctoral student and could explore things from different perspectives. Hence, it was apparent that, the instructor does not encourage his foundation year students to question authority in a scientific and engineering context, because scientific facts are established through experiments, On the other hand he acknowledges that science advances through questioning other people's work, which is not necessarily wrong, but incomplete, and needs further investigations. This, however, shows a conflicting view between him wanting to question authority for scientific development, and at the same time not encouraging his students to question the established facts due to their level of study being in the foundation year.

Practical Skills

One participant also defined critical thinking skills within engineering context as *Practical Skills*. *Practical skills* were discussed together with self-awareness and confidence in solving practical problems with basic common sense.

Example:

i. *I think it's ever-changing. (Laughs) sort of for engineers … the confidence to try and solve the problem and to have an idea of what the answer should be. So, I mean if a student's doing a problem and they come out with, you know the length of a table is going to be 3 kilometres long they put that as answer not thinking a table 3 kilometres long doesn't sound right and to think back and check. So, have an idea of what it means in the real world and that will be difficult to teach because that will need experience as well … like coming up with an idea, but it takes 4 years to build when you've got 4 months (laughs).*
(MI09_MT_F_N_UY)

Thinking in a practical sense requires critical thinking. However, (MI09_MT_F_N_UY), believes that to have practical skills, students need confidence to try to solve real life engineering problems. However, it is difficult to teach practical knowledge or common sense as it needs a good understanding of the feasibility and practicality of an engineering problem, which comes through experience.

Asking questions

Critical thinking skills are also defined as the ability to *Ask Questions* by one participant, after some expressions of uncertainty and hesitations.

Example:

i. *My goodness! (_) It's tough isn't? Because, you got to be careful you're not just thinking about deep knowledge. I'm not even sure really that we're always right, asking the right questions to bring out, to encourage the use of critical skills. I'm not sure whether we are as bad as the students in some ways that we just ask for something, a difficult concept that they could have learnt without critical skills … well, I'm not sure whether we are expert enough to bring out (_) but we do ask them, we do know how to test deep knowledge deep understanding. We know how to do that, but do we know how to get them to answer the question? But, make them use their critical skills and then, make use of the critical skills, a little use of critical skills and middle use of critical skills. You know, it kind of works but how do I define it? (_) I'm almost too frightened to go there. It's … it's all about asking questions isn't it? You sort of asking the question all the time. You're not taking things for granted.*

> *Again <u>asking yourself a set of several questions</u> isn't it? 'What's going on here? Is it this? No. Is it that? No. If this element is introduced, what change will it make and will it make a change at all?' It even frightens me to even think about it … I struggle with this things because reflection, creativity, critical you know, what are these things? How do they overlap? It's almost into the world of philosophy, I know I being kind of (laughs) I know people are experts in this sort of thing. When they talk to me it spins around my head. It's not something you can look in a dictionary and find out what it is and more I know about it the more it spins around my head.*
> *(MI07_EE_M_N_UX)*

(MI07_EE_M_N_UX) in trying to define the concept also took time to reflect, as seen in the many pauses between his responses. His hesitation also shows, his own critical thinking allows him to also ask many questions to himself suggesting that he himself is not certain on what critical thinking entails.

Creative and Critical thinking

Creative and Critical thinking is another term used by one participant to conceptualise critical thinking in civil engineering context.

Example:

i. *They need to be <u>creative problem solvers</u> because there's always <u>new problems that need a creative approach</u> … I mean, there might be a bridge builder, a civil engineer that might need to build a bridge where a bridge might not have been built before in a geography where nothing has ever been tried and tested before. It might be in a strange environment, it might be hot, it might be cold … it might be you know in Arctic Circle. You know it's difficult to do anything and you have to be creative in finding a way around the problem … <u>creativity and critical thinking is complementary</u> and they almost can't be separated can they? Because it's okay to think about an idea, but to be successful using that idea use critical thinking to put into practice.*
(MI07_EE_M_N_UX)

Weighing views

One participant from Humanities defined critical thinking as *Weighing Views*, giving a more general view than the rest of the participants, who have in one way or another included reference to science or engineering context to define critical thinking.

Example:

i. *Critical thinking skills is the (_) ability to show that you can (_) look at a situation or an argument, problem, understand the range of different views about that problem, and then move beyond just* *understanding them to actually forming your own coherent arguments about either arguments, or problem or something like that by weighing up the strength and weaknesses of other positions. (MI08_EES_F_N_UX)*

When asked whether she was referring to general critical thinking skills or critical thinking skills for engineering she expressed that she was uncertain, but said that her views were more focused on students with English language deficiency.

Example:

i. *I think in terms of, some sort of <u>weighing up other views or other things</u> and not just weighing them up but then going somewhere with it yourself. Weighing them up to some sort of conclusion involving describing one view to another view.*
(MI08_EES_F_N_UX)

Analysis of Conception of Critical Thinking category using Blended Conceptual Framework for Critical Thinking for Foundation Year

The analysis of the *Conception of Critical Thinking category* shows compatibility with Dewey's Logical Considerations (DLC), (1910) with Paul, Elder and Niewoehner (PNE), (2006) and with the Conceive Design Implement Operate (CDIO), (2011) conceptual framework for critical thinking for foundation year. Nevertheless, most of the definitions provided by the module instructors were focused on critical thinking for scientific and technical skills as in the CDIO critical thinking framework, followed by constructs found in PNE, which has elements of developing students' critical being, and finally DLC on general critical thinking skills.

The analysis overall has produced quite a wide range of definitions by module instructors. Most of their definitions were noted to have direct links to the content of the module they were teaching.

6.4.2 Pedagogy Category

The interview analysis shows that participants ways of conceptualising critical thinking skills for engineering has a direct link to their previous experience and their involvement in science, engineering or English for Academic Purposes. Their background was also noted to have some close links to their pedagogical choices as module instructors. The approaches discussed by the participants were coded as *lecture*, *interactive teaching*, *traditional method and combination of lecture and in-class practice*.

Coding system for *Pedagogy* category

(i) Lecture
(ii) Combination of lecture and in-class practice
(iii) Interactive teaching
(iv) Traditional method

Lecture

Most participants from engineering mentioned the *Lecture* with *In-class Practice* as their regular mode of teaching. They explained they use lecture mode to explain theories and concepts, which students were expected to understand well. The tutors also described lectures as an opportunity for giving examples, and justified them as an input and foregrounding session.

Example:

i. *Lectures are delivering you know materials, that's the main purpose of it. We don't do practice in lectures, we have workshops to do practical, examples and that. In lectures I do give examples while I introduce a new theory or principle, I give them examples for, to help students to understand. I do ask questions but there's no Q & A you know, in the form of Q & A sessions. So, I do give them little breaks at times if it's too, you know dense or intense, and ask them questions, give those more examples, give those lots of examples, or just the application examples. I also show how you work through in the classroom, and on the board. So, I don't think it's enough to be honest … we have one lecture forty five minutes putting over a lot of materials. In there, students find probably some students who have little background may find it really hard to follow forty minutes of teaching. But some, on the other hand, for foundation year it's really strange because some students have very strong background and they find it boring.*
(MI04_EP_F_NN_UX)

Although, (MI04_EP_F_NN_UX) explained the rationale for conducting a teaching session in lecture mode as an in-put session to introduce theory or principles and to show application examples, it was not clear if critical thinking was incorporated in the lectures, for example when displaying engineering designs, or questions, which could allow students to engage critically in an engineering problem.

Combination of lecture and in-class practice

It was noted from the analysis of *Combination of lecture and in-class practice*, that Post Graduate Teaching Assistants (PGTA) were mentioned together with problem sheets and practice.

Examples:

i. *It's a full forty five minutes lecture, I tend to have lecture notes which I work around. I can't just stand and read the lecture notes to them (laughs), but I have lecture slides that I put up and work around those, and then I have a series of work problems that I work through slowly on the white board for them. So they can see and that works, and then for each two hours of lecturing they have a two hours problem class where they have problem sheets. So, they can go work through problems under the PGTAs. Umm, so it is essentially all we do is talking. I do encourage questions, I don't get many, but I encourage them. I mention at the start of each lecture "if you've got a problem please don't worry about sticking your hand up and interrupting me at the end of a sentence", but they're a bit slow coming forward.*
(MI05_MS_M_N_UX)

ii. *My style I'm always conscious that you've got to keep them engaged. So, I do move around a lot and keep them awake and I do a bit of talking and then go on the white board and then I do a bit of power point, so, I'm going from one thing to another. I do move around. I impersonate particles, you know, like an electron is a particle that moves along a wire that's electricity. I am an electron walking along and dancing along and a bit of performance, really, but it engages them and I have a bit of fun.*
(MI07_EE_M_N_UX)

iii. *Basically, the lectures are divided into quite small units. I explain to them a notion or something and try to be plausible. So, I kind of, I say Maths is not religion. I don't like to give them formulas and say this is what you remember. I somehow would like the formula to talk to them and I try to make it plausible kind of so that they could understand, it could make sense for them, and then they use it on some simple examples.*
(MI01_MT_F_NN_UX)

iv. *It tends to be, go for theory, I personally use PowerPoint quite a lot, just because you can present a slide of information, and maybe might be some theory, then a problem, a worked problem, now go through the solution, something for them to try. Try to break things up a little bit, so it's a very much case of not just think, Bloom's Hierarchy, you know not just try to give them knowledge all the time, you've got to get them applying it and ideally then start to apply in new situations as well.*
(MI10_EE_M_N_UY)

The analysis of *Combination of lecture and in-class practice* shows evidence of in-class practice in critical thinking. (MI05_MS_M_N_UX) explained his teaching sessions were conducted by showing application examples to work out problems for students to practice in class in the Mechanical Science (MS) context. *Asking questions* is an aspect of critical thinking, and this was also encouraged by (MI05_MS_M_N_UX) during his teaching sessions, even though not many students participated in this. Besides that, (MI07_EE_M_N_UX), (MI01_MT_F_NN_UX) and (MI10_ET_M_N_UY), also noted including some critical thinking activities in their teaching sessions, for example, through metacognition and knowledge integration within Electrical and Electronics (EE), Mathematics (MT), and Electrical Technology (ET). However, it was also apparent from the analysis that most of the critical thinking practice was limited to technical and scientific skills, without including practice in developing students' critical being.

Interactive teaching

Interactive teaching was mainly mentioned by one participant in the English language pathway programme. This instructor reported that she would not speak for more than for five minutes at a time.

Example:

i. *So very interactive to get them out, physically out of their seat as well and get them to do things in groups quite a bit … very little in terms of like a lecture. I don't think I would speak more than for five minutes at a time … at any point of the lesson they could ask questions and you know, and at the end of explaining a concept I would ask if they had any questions.*
(MI08_EES_F_N_UX)

Critical thinking is an active process, therefore, the *Interactive teaching* session was also noted to have encouraged students' active participation in the class, and they were also encouraged to ask questions by the instructor. Nevertheless, it was not clear if the interactive sessions involved critical thinking activities, and whether the types of questions students were encouraged to ask had elements of critical thinking.

Traditional method

One participant mentioned *Traditional Method* when come to teaching when talking about English language classes in the language pathway programmes. This participant expressed disappointment with the way the module was structured which was more grammar than skills based.

Example:

i. *MI06:* *Well, the way the module is set up is basically, what's it's called, teach, what is the traditional model, I don't, I forgot now, my teacher training has gone again. Yeah, basically, the way the module is set up is quite traditional in its approach. Umm, so semester one is a massive focus on sentence structure … so really, I present them with a grammar point, they do a bit of practice, you know. A bit of presentation practice, don't know what ever it is, I still can't remember. So yeah, I mean it's very, I would say you* *know, it wasn't very exciting. But you know, the course said, so I had to teach them, you know, 'adjectival clause', is this week and you know that …*

I: *More focus on grammar?*

MI06: *Very focused on grammar and much less focused on skills.*

I: *So, do they have classroom practice?*

MI06: *Uhm, yeah. No, some of it I made them do or bits of it I made them do with me in the class and I go around and monitor, and see what they are doing, and some of it will be for homework.*

I: *So, if you give in-class practice what, how much time you allocate for this?*

MI06: *I don't know, it varies. Sometimes I get them, you know I show them, describe what an adjectival clause is and then I get them to do a question. Then we talk about it again sometimes a bit of analysing a bit of writing or something. I get them to do it together, feedback, or I get them to do right kind of sentences, and check with their partners and discuss what they had written. They're very bad I have to say at pair work and group work, so to be honest I just gave up because they don't bother.*

(MI06_EES_F_M_UX)

The analysis of *Traditional method* employed by (MI06_PWA_F_N_UX) shows no evidence of active learning, or critical thinking engagement within the language support Pathway A (PWA) programme. The instructor explained PWA programme is largely focused on teaching of grammar without reference to academic skills, therefore, the teaching is largely conducted in what she calls the *Traditional method*.

Analysis of *Pedagogy category* using Conceptual Framework for Critical Thinking

The Pedagogy category has shown some evidence of critical thinking practice in the classroom, mainly in Mathematics (MT), Mechanical Science (MS), Electrical and Electronics (EE), and Electrical Technology (ET), with very little, or no evidence in Engineering Principles (EP) and English support Pathway A (PWA) modules. This critical thinking practice was largely influenced by mathematical and scientific thinking, which aligns with the CDIO critical thinking framework with limited practice in developing students' critical being as maturing engineering students as in PNE, and DLC general critical thinking skills, for example using practical skills to solve real life engineering problems.

In sum, the analysis on the *Pedagogy category* shows the different overall approaches taken by the participants to conduct their class. However, the *Pedagogy* category was closely linked to the *Practice* category as the participants consistently reported that support classes, workshops, and weekly problem sheets supported their modules.

6.4.3 Practice Category

Comments allocated to the *Practice* category appeared when participants were asked whether students have opportunities for critical thinking practice in the class, or within the module they were teaching. The *Practice* category was coded when participants mentioned *problem sheets*, *workshops* and *language games*.

Coding system for *Practice* category

(i) Problem sheets
(ii) Workshops
(iii) Language games

Problem sheets and workshops

Problem sheets were coded when participants talked about the extra practice students received outside of the classroom for all modules, which was not covered in lectures. Participants explained that students receive extra support at workshops to answer the problem sheets, in which students have to attempt the questions independently first, then bring them to the workshops for answers and further support, therefore, the *Problem sheets* were coded with *workshops*.

Examples:

i. *For my case, I do <u>two lectures a week</u> and then they have <u>one problem sheet</u> per week and uniquely on my course EE they do the <u>problems on-line</u>, so they answer the questions on-line which they prefer, I don't know whether they always write in the evaluation that they prefer doing them on-line rather than attending a workshop. So, they attend workshops in MS and EP and <u>Maths but they much prefer my method</u>, but it's just different way of doing it.*
(MI07_EE_M_N_UX)

ii. *The <u>problem sheets</u> … they're given to do in workshops. They present more kind of, more complicated examples. So, <u>in the lecture there's not enough time to do a complicated example</u>, so, <u>they learn the concept on a simple example</u>, and then they like <u>reinforce what they learn by working on the problems in workshops.</u>*
(MI01_MT_F_NN_UX)

The analysis of the *Problem sheets and workshops* shows some evidence of critical thinking practice through self-regulated learning and practice, as in Electronics and Electricity (EE) by doing problems on-line and in Mathematics (MT) using problem sheets. Self-regulated learning promote independent thinking, which is an element of critical thinking. This however, needs to be supported by explicit teaching, or modelling by module instructors of challenging or complex problems in the class to help students learn through knowledge integration and application of skills to find a solution within an engineering context. Although, the instructors suggested that students will have opportunities to practice more complex questions or problems in the support class or workshops run by support tutors, or Post Graduate Teaching Assistants (PGTAs), this does not show concretely, that students are actually using the workshops in this way. For, not all students may be intrinsically motivated to do the problem sheets independently, or students may not attend the workshops. As such, it was not concretely evident that students have the opportunities to practice and develop their critical thinking skills using *problem sheets* or attending *workshops*. (Unfortunately, it was beyond the scope of the study to interview PGTAs or to observer these workshops.)

Language game

Language game was coded when one Humanities participant claimed that students were learning critical thinking through a vocabulary game in the language module.

Example:

i. *As far as lab reports go, there are, you know obviously analytical aspects towards the ends, but what they're learning really it is procedures. They're just learning procedures really, so how to, you know, how to use equipment in the lab, how to follow a lab book, how to follow the health and safety, you know how to report things, being accurate, do you know what I mean? that kind of, but to be honest they're doing all that in their other modules they're not doing that with me, so critical thinking, umm, for example you know, you were in my class when we played the vocabulary game on board. (MI06_PWA_F_N_UX)*

In the Language game category, though an analytical aspect was mentioned by (MI06_PWA_F_N_UX), it was not related to the language support module Pathway A (PWA), but rather to other modules. Language game requires active participation of students, but there was no evidence whether the game involved thinking skills or was based on grammar items or technical vocabulary.

Analysis of *Practice category* using Conceptual Framework for Critical Thinking

The *Practice category* showed some evidence of critical thinking activities, which promote critical thinking through self-regulated learning. The students receive problem sheets for each module from their tutors, and the students are expected to solve these problems independently. Based on the analysis, the practice was concerned with scientific and mathematical thinking, and therefore mainly related to CDIO conceptual framework with limited practice as in PNE in developing students as critical beings, and none on DLC on general critical thinking skills.

The *Practice* category was mainly used to identify to what extent students have practice in critical thinking skills within each module. It was noted *Problem sheets* and *workshops* were used to provide opportunities for students to practice their critical thinking skills outside lectures. A *Language game* was also mentioned by a language instructor as in-class practice for critical thinking skills but with no clear evidence that the game promoted critical thinking.

6.4.4 Language Category

The *Language* category identified in the interview analysis when participants were asked to respond to the question whether English Language plays a role for students' learning and applying skills in their foundation engineering studies. Participants' comments on language are coded with three subcategories: *English Language*, *writing laboratory reports* and *communication skills*.

Coding system for *Language* category

(i) English Language
(ii) Writing laboratory report
(iii) Reflective writing

English Language

English Language was coded when it was mentioned directly by the participants in the context of understanding content knowledge during lectures in Engineering Principles (EP) by (MI04_EP_F_NN_UX), and in reformulating problems in Mechanical Science (MS), by (MI05_MS_M_N_UX). (MI10_ET_M_N_UY), on the other hand, mentioned English Language with reference to engineering vocabulary in Engineering Technology (ET), (MI07_EE_M_N_UX) related English Language to reflective thinking, and (MI06_F_PWA_N_UX) compared English Language with mathematical and computer coding language.

Examples:

i. *I think it is <u>almost clear that the English students,</u> you know students with <u>English language</u> background <u>would definitely take more in during the classroom, than obviously students who didn't have</u>, you know, <u>enough</u> <u>English</u> background. Because, you know it's just that they have a barrier, whether it's a very big barrier or a small barrier, they feel <u>some of the things we talked about in the lecture room they don't understand</u>, and <u>they have to make a note and go back to check.</u> (MI04_EP_F_NN_UX)*

ii. *I:* *So, for engineering studies on the whole, how important is language?*
MI05: *Umm (_) <u>as long they understand basic English</u>, and I mean, <u>I don't see it as</u> <u>critical.</u> Umm, <u>we take them with</u>, which obviously <u>one point lower language qualifications</u> <u>than they need</u>*

for a full degree … they get supplementary English on the course. They get, I think Language Pathways at a certain level, where they have extra English lessons and miss some of the, depending what their degree option is, they miss either Electronics or Engineering Principles … I don't think I have issues with it in my course, but I could see in some of the courses unless the actual problem is specified very clearly. Umm, they might have trouble actually forming the problem in the first place. In fact as I recall, there're couple of Maths homework sheets which I think they've been altered where some of the overseas students couldn't understand what they've been asked for.

I: *Okay*

MI05: *Umm, I see some of the UK students couldn't understand what they've been asked for either (laughs).*

(MI05_MS_M_N_UX)

iii. *MI07:* *But, usually Chinese are following the language pathways, they have this obstacle of English language. It's a real, I mean when they do their work for the pathway, when they write a piece of work for their English language I think it's very difficult for them to get through the work because they're struggling with the language*

I: *so, they couldn't write well, is not they couldn't reflect well?*

MI07: *I think, it's difficult to identify any reflection in a piece of work that isn't well written, I don't think.*

(MI07_EE_M_N_UX)

iv. *MI06:* *What I'm saying is they can get things done, they can understand and create and do things in other languages like Maths and computer languages. So, you don't need to be fluent in English in order to programme a computer, you don't need it, and to read a manual to be honest, you don't need to be fluent (whispers), you don't, do you?*

I: *Okay*

MI06: *If you look at the engineering books, you look at the kind of texts in there it's very you know, it's very instructional texts, you know and you've a lot of other clues like equations, diagrams in order to decode what the written text is saying using a lot of support and information. They don't just you know, they will end up doing that, they will end up having to read journal articles, but again they'll be supported by theorems which they can understand without having to do any English, Maths diagrams. You know, you look at a circuit board, which doesn't require English. So, the demands for their language skills are you know different than they would be for other disciplines.*

(MI06_EES_F_N_UX)

v. *They need to understand the language, need quite a good level of knowledge of language, and engineering has a large vocabulary, terms which we try and teach them to use those terms and some of them are better at them than others. Probably, that is mainly related to their academic ability …*

> *We don't get many people who're not fundamentally good at English, we don't tend to experience that on the extended programmes, they have got a good grasp of English, they may not be good at writing, some of them are not, their written skills are not as good as their spoken, but we do try to … get them confident in technical terms.*
> *(MI10_ET_M_N_UY)*

These disparate comments show that the importance of English Language in the context foundation year had mixed views from the module tutors. (MI04_EP_F_NN_UX) and (MI10_ET_M_N_UY) explained English Language is important in understanding both content and engineering vocabulary, particularly for non-native students, who seem to usually struggle more than native students. However, neither related the language with students' critical thinking ability to solve engineering problems. On the other hand, (MI05_MS_M_N_UX) did not find students English Language proficiency to be an issue provided they understand basic English, as far as his Mechanical Science (MS) module was concerned. However, he claimed it might be an issue in other modules such as Engineering Principles (EP) and Mathematics (MT), particularly in formulating a problem if the instructions were not clear. Similarly, (MI06_PWA_F_N_UX), as a language support tutor also agreed that engineering students will be supported by mathematical knowledge and coding skills to solve engineering problems did not link the language influence to students' ability in applying critical thinking skills. Unlike the other participants, (MI07_EE_M_N_UX), mentioned English Language with direct reference to Chinese students following language pathways, and their ability to engage critically in reflective writing. He claimed that, if they struggle to write in English, it is difficult to identify any reflection in their writing, because they lack clarity.

English Language was also coded when one participant mentioned that accuracy in the language was what was required in the marking criteria for the language pathway programme.

Example:

i. *I:* *So, you mentioned about, when assessing or marking their work you focused more on language rather than the analytical bit*

MI06: *Yeah, I don't mark them on that. It's not in the assessment criteria and I'm just, so I said to them, 'I don't care how stupid your suggestion is … I said, 'I don't, I'm not here to judge, but I'm here just here to work out if you've put in a decent sentence' … to be honest … I'm not in a position to judge what is a sensible question for anomaly in a Physics experiment, you know.*
(MI06_EES_F_N_UX)

Commenting on English Language and assessment criteria, (MI06_PWA_F_N_UX), admitted that in her language module, the assessment criteria did not include critical skills. Therefore, it seems students might have given nonsensical answers, but that would not have affected their marks as long as their statements were grammatically correct.

English Language was also mentioned by a participant when talking about thinking, however, no direct reference was made to FY students.

Example:

i. *I think everybody is going to be different because once somebody understands even if their English isn't very good even once they understand what they have to do and the processes they have to carry out surely they're going to develop their critical skills even if they translate into their own language which I know students do. They think in their own language, it takes time to start thinking in English. I know that's a fact because I've taught PhD students before that have been in this country for several years and I said, 'what language are you thinking in?' Sometimes they say their own language, sometimes they say' English but I haven't been thinking in English for very long. When I go home to China to Greece, or whatever for my holidays, I start thinking in Chinese and Greek again but only after a couple of weeks'. So, it's very interesting, really. I've no idea what those answers are. (MI07_EE_M_N_UX)*

It is apparent from the analysis that, almost all the participants agree English Language is important. However, it was not perceived as a barrier which could stop students from thinking and working within their engineering study at the foundation level, as the language module instructor, (MI06_PWA_F_N_UX) pointed out. Engineering is basically an instructional language with lots of other clues such as equations, theorems, or diagrams, which they can understand and do not require very advanced English Language. Nevertheless, this could be different for other disciplines.

Writing laboratory report and reflective writing

Two codes were used for references to students' writing; *lab report* and *reflective writing* to cover any direct reference to English Language and to British, international, mature, and Chinese students.

Examples:

i. *Support class in semester one I was very enthusiastic to make my students in my class turn up for the support class and what I did was identify areas of weakness or … specifically, particularly related to the types of writing and things. So, what I did was I went and found out what writing task they had on other modules and we do a lot of specific work in support class on, for Routes to Success they have to do reflective writing and none of them have done anything like that before so we did some work on reflective writing. Also, they had to start writing up lab reports which is another specific style of writing which most of them hadn't engaged in certainly not in English. So, we did quite a lot of work on how to write the language and grammar you need for writing lab reports and then it was just really responding to students' needs*

(MI06_EES_F_N)

ii. *MI07:* *We don't measure their critical skills, and I don't know much about them. I don't know how to identify them. I can only perhaps only guess based on my experience (_) you know. I can't even guess, but as usual, and this is totally subjective I've got no evidence to back this up. As usual students, but no obviously I'm gonna say students from the UK perhaps. I've a greater awareness of this sort of thing than with international students, but, I think that goes without saying doesn't it? But, I might me guessing, I've no idea actually. I honestly don't know. Because you know, I do test reflective skills because I asked them to write a reflection portfolio but that is not critical, that just reflective. You know, there's some students better than the others at identifying their strengths and weaknesses and putting strategies to overcome their weaknesses and so on, that's not necessarily critical is it? I don't know what it is actually*

I: *So, when come to reflective writing, who provide a more meaningful information?*

MI07: *Mature students are always best at reflecting*

I: *So, it doesn't matter who? Is that because of their life experiences?*

MI07: *Yeah. Yes, but again British students, UK students are better at reflecting. But, I'm not sure, that's because they're more willing to engage with the exercise, and they understand more of what they have to do because they've done it before, because they do it at A -Level. Whereas, the Chinese students are perhaps not so good at reflecting, because, maybe they don't understand the exercise, maybe they do reflect, maybe they don't know how to do it in English, I don't know*
(MI07_EE_M_N_UX)

The analysis of the data on lab report writing had no direct link with critical thinking skills. However, reflective writing was directly connected to critical thinking skills, even though, (MI07_EE_M_N_UX), was uncertain if reflective thinking is critical thinking.

Analysis of *Language category* using Conceptual Framework for Critical Thinking

Overall, analysis of the Language category shows some limited evidence for links between language and critical thinking skills, from instructors' perspectives. The critical thinking skills present in *Language* category were mainly reflected in CDIO statements on communications in English, followed by DLC on reflective thinking, and PNE on clarity as one of the intellectual standards for sound reasoning to develop engineering intellectual traits.

6.4.5 Maturity Category

Maturity is another main category identified in the interview analysis when participants talked in particular about the characteristics of mature students and their capacity to develop critical thinking skills.

Examples:

i. *Sometimes, mature students struggle a little bit with it, I think. Because, partly it's coming back to learning is difficult, and especially if they haven't studied Maths for a long time then perhaps those underlying skills that help support the programme the way of thinking the Mathematical way of thinking might be hindering them. But, I don't have any figures to say that lots of mature students struggle. But, there are a few mature students who definitely struggle … like almost certainly if they've not studied. If they not gone straight into studying engineering out of school, possibly because they didn't do Maths at school. They weren't keen on Maths early in their studies so, by the time they reach they suddenly realise they need it, it can be hard to learn that, that sort of thing.*
(MI02_CW_M_N_UX)

ii. *The ones I would say, looking at it from just a purely logical thinking point of view have the biggest issues, I would say mature students for some reason.*
(MI05_MS_M_N_UX)

iii. *I:* *So, do you think maturity is important in critical thinking?*
MI05: *I would say no, but I suppose it depends on what you mean by maturity? I think I've got three kids of my own and they've got no problem with critical thinking and probably at quite a young age. In fact I think children don't, if they're introduced to it properly … it's funny I was talking to* [redacted] *just about fifteen minutes before you turned up and I don't think critical thinking is sufficiently taught in schools, well, it certainly wasn't when I went to school. It's assumed you picked it up from doing maths, from doing physics. Umm, I don't know what they're teaching now, I think it's something that needs to be, the ideas behind it need to begin when much younger I would say. Although, eighteen I suppose they're still flexible enough*
I: *Right. So, maturity …*
MI05: *I wouldn't say it's really an issue, in some ways maturity well can be a handicap (_)*
(MI05_MS_M_N_UX)

iv. *I think it's more personality, you know, because some students are really very young and still like engaged and some are old and disengaged, and some are old and engaged, older I mean. So, I think it depend more on personality.*

(MI01_MT_F_NN_UX)

v. *We have mature students who did really well because they have more understanding of why they're doing this and we have younger students who, you know are very immature but they are very bright, they know, you know they wanted to do engineering, and they do very well too. I don't think it's essential you know, either younger or older. But, what I've found is that younger students who, in education you know, are more close to what is happening at universities, they probably cope better, but mature students because of the more complicated background they maybe are married or have a family you know, this may affect their studies more than the younger ones. They just come here to study, but it is not so critical that you have to be at certain age, I don't think that's, because I've seen mature students who did really well, and because they have the experience of working they know now that the opportunity to study is quite , you know important to them. They actually work very hard and get to what they set out to get, to achieve.*
(MI04_EP_F_NN_UX)

vi. *Mature learners when they come in, they, some of the learners beginning are very lacking in confidence, and some of those learners started going out to get extra Maths tuition, that sorts of thing. But, the general feeling was, though they didn't need it, they go out to get extra support for Maths. But, what they needed was somebody, to kind of reassure them that what they're doing is correct, and in the vast majority of cases, those learners got through that, and now once they have got their confidence, they just progress forward, and, as their study progresses forward, they tend to be more academic, and they get where they want to be, that particular group even though they encounter difficulties, they don't just leave it all, which I'll give them rather than doing it for them, they just keep on going and going, they wouldn't give up.*
(MI10_ET_M_N_UY)

The interview analysis shows that there is a relationship between *Maturity* and the students' ability to think critically. The majority view that mature students do have some issues in adapting to critical thinking in the engineering foundation year. (MI05_MS_M_N_UX) mentioned that *Maturity* at times could be a handicap. Another participant (MI01_MT_M_NN) mentioned personality that students' dispositions are more important than maturity in engaging in critical thinking. However, participants, (MI04_EP_F_NN_UX) and (MI10_ET_M_N_UY) found that mature students have strong commitments in their studies, work very hard, and never give up until they get what they set out to achieve. This perseverance in achieving the desired goal is one of the essential engineering skills, which require critical thinking skills.

Analysis of *Maturity category* using Conceptual Framework for Critical Thinking

The analysis of the *Maturity category* shows a direct link between mathematical skills and critical thinking, and attitudes towards critical thinking. This perceived centrality of *mathematical thinking* skills aligns with the CDIO critical thinking framework, specific to engineering. Besides that, students' attitudes as mature students towards critical thinking is also present in the CDIO statements on attitudes, thought and learning as personal and professional attributes. *Maturity* and critical thinking also appears in PNE as desired *Intellectual Traits* as in intellectual perseverance and confidence in reasoning. However, there was no evidence of DLC critical thinking framework linked with the *Maturity category*.

6.4.6 Culture Category

Culture was mentioned when participants were asked to respond about the types of students that they observed to have problems with critical thinking skills, though culture was coded only when participants mentioned the word culture directly. There were just two instances where culture was mentioned, firstly by one participant (MI04_EP_F_NN_UX) when sharing her experience as a non-native module instructor and secondly by participant (MI07_EES_F_N_UX) talking about her non-native students.

i. *If we ask a question to a class, it's always those students answering, but I would like more students to get involved. But, then students don't do that. I would actually personally like to say, 'okay so and so can you tell us, what you think', but then the student might say, I have students doing that saying, 'I don't know', you know, and very bluntly and they don't say anything. You just think they're not happy for you actually to ask them directly. So, there is a difficulty between the two methods, you know, how do you deal with it? So, some students are all willing to answer, and they are very quiet, when you actually ask them they speak out. But, you don't know who's going to do that. So, you may get a blank reply saying, 'why me?' so, I understand, I mean if it's in China all students would be quite polite. If you ask them, they would try to answer and they wouldn't say anything rude, but here the culture, especially some English students, you ask them, they don't know, they can be very rude as well, so, which can be a very embarrassing situation. So, I understand the culture is different because people don't like to be put you know under the spotlight. So, I tend not to do that to, most of the time I would just let the person who wants to answer, but again that is not ideal because you always get those people, yeah*
(MI04_EP_F_NN_UX)

ii. *I:* *So, do you think maturity is important for critical skills?*
MI06: *Absolutely. You can even see, you know* [redacted] *is deaf and has other problems as well is not only deafness, but his ability, I mean it's also cultural we have to say. But, so his ability to give you know what you, like it's more mature complex*

> *responses to things was much better than the rest of my group but, there's also culture,, cultural differences because they're all different nationalities,*
> *(MI06_PWA_F_N_UX)*

The analysis of the *Culture* category suggests that culture is rather vague without a clear definition on how this relates to students' ability in critical thinking. Both the participants, (MI04_EP_F_NN_UX) and (MI06_PWA_F_N_UX) have described culture in the context of students' country of origin, and how this influences their critical engagement in the class. This, however, did not answer clearly the question as to how students' cultural background affects their ability to learn and apply critical thinking skills.

Analysis of *Culture category* using Conceptual Framework for Critical Thinking

The overall analysis of the *Culture category* shows no clear link to critical thinking, therefore, none of the conceptual framework for critical thinking can be matched with the *Culture category*.

6.5 Conclusion

Analysing using the *Conceptualising Critical Thinking category* clearly showed participants' definition of critical thinking was very broad. The definitions varied with most defining critical thinking skills for engineering as identifying and *solving problems* followed by *mathematical thinking*. The rest of the definitions were quite diverse and there were obvious overlaps between scientific and philosophical approaches in defining critical thinking by the participants. However, *creative and critical thinking*, being *self-critical, asking questions, realising limitations, having a curious mind* and *questioning authority* were more focused and engineering (scientific approach). Only, one Humanities participant (MI08_EES_F_N_UX) defined critical thinking as *weighing views* showing some connection to sound reasoning and desired outcome in an argument (philosophical approach). This may be due to participants' previous background and experience in teaching English for Scientists and Engineers and language programme, where in some situations thinking was more context-bound, and in language criticality is defined by the ability to argue effectively with sound reasoning.

Analysing using the *Pedagogy category* showed the mode of teaching employed by the participants. There was no clear evidence that students had opportunities to learn and practice critical thinking in lecture mode, or interactive teaching or through traditional method. However, when combined with in-class practice, there was some evidence of critical thinking modelling for students to learn and acquire the skills as employed by (MI01_MT_F_NN_UX), (MI05_MS_M_N_UX), and (MI07_EE_M_N_UX) in the engineering modules. Contrarily, there was also disappointment expressed by one participant from the language pathway programme (MI06_PWA_F_N_UX) that the choice of her approach to teaching was restricted by a prescribed syllabus, which was heavily focused on grammar and not skills. This resulted in her adopting traditional what she called a traditional method of teaching, which lacked practice in critical thinking skills.

The category of *Practice* had a direct link to *Pedagogy*. However, the analysis showed it was unclear whether students received sufficient practice on critical skills since the participants expressed uncertainties about the type of critical thinking skills required at foundation level and made it clear that was more on engineering theories and concepts than thinking skills. One participant (MI05_MS_M_N_UX) mentioned that critical thinking skills are inherent in maths, yet another participant (MI07_EE_M_N_UX) said that maths does not involve critical thinking skills as much as Physics and Mechanical Science.

Language was another predominant category, which was mentioned in the context of its role in critical thinking, report writing and reflective writing. English Language was also mentioned as a tool for communicating ideas effectively as engineers, which an experienced participant (MI03_WS_M_N_UX) claimed to be lacking among foundation year students. It was clear from the analysis that almost all of the participants agreed that English language is important for engineering and thinking, however, students' possible deficiency in the English Language will not stop them from thinking as they could be thinking in their own language or using mathematical clues, diagrams and computer codes as expressed by (MI06_PWA_F_N_UX).

Maturity is another main category appearing in the analysis. *Maturity* is closely linked to mature students and attitude towards learning. The analysis showed that participants found not consistent correlation between age and maturity, age and critical thinking skills. For example, it was noted by one participant (MI01_MT_F_NN_UX), that it was more related to personality, while another participant (MI05_MS_M_N_UX) viewed maturity at times as a handicap.

Culture was another main category which appeared in the interview analysis, but was rarely mentioned. Participants, (MI04_EP_F_NN_UX) and (MI06_PWA_F_N_UX) mentioned culture but without any connections to students' critical thinking.

Overall, the analysis shows there were some subtle conflicts between module instructors' *conceptualisation of critical thinking* and their *pedagogical* approach, showing limitations to the faculty commitment in providing sufficient practice for students to learn and develop critical thinking skills in foundation year. Besides that, there were some conflicting views between English language and its influence in students' critical thinking ability.

Chapter 7 The Place of Critical Thinking in Course Documents

7.1 Introduction

This chapter presents the analysis of the module profiles used in the engineering foundation year programme at the two selected universities in the UK, which run a similar foundation programme. The two foundation year programmes were engineering Foundation Year (FY) at University X and Integrated Foundation Year at University Y. The selected modules were compulsory taught modules in the programme for the academic year 2014-15.

The research is interested in investigating how the engineering students develop their critical thinking skills in their foundation year. Therefore, it was important to analyse the course documents to find out to what extent the module descriptors emphasise critical thinking skills within the stated aims and learning outcomes, knowledge, skills, teaching and learning activities, academic English Language and assessment. The analysis is useful to triangulate the data with the students' and module instructors' interviews on students' development of critical thinking skills, to explore whether they are in agreement, or in conflict with each other.

The documents were checked in order to determine whether critical thinking skills were evident in general curricula for the foundation year programme, and other local course documents, and if yes, what types of critical thinking skills are given preference. The aims and the learning outcomes of each module were analysed. Any mention of language and culture in the documents was also included in the analysis to find out if there is any alignment with student and tutor interview reports.

7.2 Module Profiles

The module profiles used as course documents in this study cover almost all the modules taught in the foundation year programme at the two selected universities. The list of modules used for the document analysis is shown in *Table 7:1 (on p182)*.

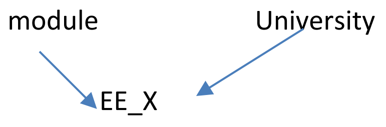
The module profiles were available on-line on the foundation year website for University X, however, approval was needed from the foundation year Programme Leader from both the universities for access. Hence, a formal request was made by e-mail and in person to the

Programme Leaders to access the course documents by providing evidence of university research ethical approval *(Appendix C on p 271).*

Table 7:1 Foundation Year Programme Modules used for the document analysis

NOS.	MODULE PROFILES (code and title)	UNIVERSITY	ID
(i)	GENG 3894: Foundation Year Description for Engineering	X	EFY_X
(ii)	GENG 0016: English for Engineers and Scientists	X	EES_X
(iii)	Language Pathway A	X	PWA_X
(iv)	Language Pathway B	X	PWB_X
(v)	GENG 0004: Electricity and Electronics	X	EE_X
(vi)	GENG 0005: Engineering Principles	X	EP_X
(vii)	GENG 0003: Mechanical Science	X	MS_X
(viii)	GENG 0001: Mathematics A	X	MTA_X
(ix)	GENG 0002: Mathematics B	X	MTB_X
(x)	GENG 0014: Routes to Success	X	RTS_X
(xi)	GENG 0015: Course Work	X	CW_X
(xii)	CET 004: Electrical Technology	Y	ET_Y
(xiii)	CET 005: Introductory Engineering Mathematics	Y	IMT_Y
(xiv)	CET 007: Project	Y	PROJ_Y
(xv)	COM 001: Information Technology	Y	IT_Y
(xvi)	MAT 001: Mathematics	Y	MT_Y
(xvii)	MAT 002: Statistics	Y	STATS_Y
(xviii	ENG 001: Study and Communication Skills	Y	SCS_Y

Each module identification code is composed as below:



The format of the module profiles of both University X and University Y was largely similar and descriptive, covering *module title*, *overview*, *learning outcomes*, *teaching and learning methods*, *assessments* and *foundation year structure*. Despite the similarity, it was noted there was a slight difference between the two universities, in which University X gave more details on the section on educational *aims* (v) and *learning outcomes* (vi) compared to University Y *learning outcomes* (iv), as shown in the outline below.

University X

(i) Module Title and Code
(ii) Module Tutor
(iii) Module overview
(iv) Module availability
(v) Aims
(vi) Learning Outcomes: knowledge and understanding; subject specific and intellectual and research skills; transferable and generic skills; subject specific practical skills
(vii) Summary of syllabus content
(viii) Summary of Teaching and Learning methods and Hours allocated
(ix) Summary of assessment and Feedback methods and Progression requirement
(x) Resources (reading lists)
(xi) Health and Safety

University of Y

(i) Module Title and Code
(ii) Module Tutor
(iii) Module availability
(iv) Learning Outcomes: knowledge; skills
(v) Content Synopsis and Amplified content
(vi) Teaching and Learning Methods and Hours allocated
(vii) Assessment Methods and Progression requirement
(viii) Indicative reading lists

The module outlines from both University X and University Y have almost similar information. However, Module overview (iii), Aims (v), and Health and Safety (xi), which appeared in University X did not appear in University Y. The similar information shared by both the universities was: Module Title and Code (i), Module Tutor (ii), Module availability (iv, iii), Learning outcomes (vi, iv), Summary content/Content Synopsis, (vii, v), Summary of Teaching and Learning and Hours allocated (viii, vi), Summary of Assessment method and Progression requirement (ix, vii), and Resources/Reading Lists (x, viii). As for the Module overview (iii), University X had a separate section on Summary of syllabus content (vii), while University Y combined the Module overview with the Syllabus content (v). This was also the case with the sections on Summary of Teaching and Learning methods and Hours allocated, and Assessments and Feedback, in which University X (viii, ix) has provided a separate summary section for each, (viii, ix). For the Learning outcomes, University Y (iv) did not provide any details on specific skills, while University X has categorised the skills as ‘subject specific and intellectual and research skills; transferable and generic skills, and subject specific practical skills’. Besides that, Aims (v) was clearly stated in University X, but not in University Y. It was also noted that University X has a section on Health and Safety (xi), but this did not appear on any of the University Y module profiles. A sample module profile for each of the universities is shown, University X (*Appendix J.1 on p 326*) and University Y (*Appendix J.2 on p 330*).

The total teaching and learning hours of each module in University X was 150 hours, while in University Y this was generally, 200 hours. From the total hours allocated, a large proportion was given to students’ independent study. As for the Aims and Learning Outcomes, the initial observation on the documents showed that University X had more detailed descriptions compared to University Y.

7.3 Data Analysis

The module profiles listed in *Table 7:1* (*on p 182*) were analysed using thematic analysis using NVivo 11 software. The research questions were used as a starting point to identify the main categories and themes to analyse the data. The analysis was conducted based on three different perspectives. Firstly, by analysing how the foundation year modules and other general syllabus documents for the discipline of engineering conceptualise critical thinking; secondly analysing the pedagogical aspect and student’s practice as described in the module documents; and analysing to what extent critical thinking skills were evident in the module and what types of skills were given preference.

The analysis was guided by the following research questions:

2) How do students learn and develop their critical thinking skills in the engineering foundation year programme?
    a) To what extent do students have the opportunity to practise critical thinking skills in the engineering foundation year programme?
    b) What types of critical thinking skills are exposed to during the foundation year?
3) What is faculty’s goal for students’ critical thinking skills?
    a) Are critical thinking skills evident in general curricula for the discipline of engineering foundation year module profiles and other documents? If yes, what types of skills are given preference?

The main categories and themes were first identified, then developed into coding codes based on recurring patterns of words and phrases, which clustered into themes to identify the main categories. The coding scheme used based on the NVivo 11 output is shown in *Table 7:2 Coding Scheme and Description*.

The examples of data used in the document analyses were extracted directly from the original documents using NVivo coding application to maintain their authenticity. However, the style and font were amended for easy readability. The sample data also includes some specific codes, i.e., *A1*, *A2*, *C2*, *B1*, *B2* and *S1*, which were taken directly from the documents. Definitions of these codes are drawn from, the UK-SPEC UK Standard for Professional Engineering Competence and Programme Specification of Faculty of Applied Sciences Department of Computing, Engineering and Technology of University Y. Descriptions of these specific codes are given in (*Table 7:2).*

Table 7:2 Description of Specific Codes

Code	Description
A1	Maintain and extend a sound theoretical approach to the application of technology in engineering practice.
A2	Use a sound evidence-based approach to problem solving and contribute to continuous improvement.
B1	Identify, review and select techniques, procedures and methods to undertake engineering tasks.
B2	Contribute to the design and development of engineering solutions.
C2	Manage tasks, people and resources to plan and budget.
S1	Demonstrate basic competence in mathematical modelling of simple engineering systems.

Based on the eighteen module profiles, the following main categories were identified and used for data analysis.

(i) Skills
(ii) Learning outcomes
(iii) Assessment
(iv) Pedagogy
(v) Practice
(vi) Academic English
(vii) Aims
(viii) Independent learning
(ix) Knowledge

Skills category was identified as the most mentioned category, which is closely linked to *Learning Outcomes, Pedagogy, Practice*, and *Knowledge*. Skills were identified, and coded exactly as they were explicitly stated on the document. The *Skills,* which were mentioned in the Learning Outcomes were *Technical Skills*, *General Transferable Skills*, *Practical Skills-Subject Specific*, and *Intellectual Skills*. However, the *Technical Skills* were only coded when they linked with engineering practice and engineering skills. The NVivo coding scheme is shown in (*Table 7:3*)

Learning Outcomes is another frequently mentioned category relevant to CTs, which overlaps with almost all the other categories, identified, in particular the *Skills and Knowledge* categories. *Learning Outcomes* was coded when students' target abilities were mentioned, i.e., the ability to record, analyse and evaluate data effectively, analyse and solve mathematical and engineering problems, select and use appropriate computer-based methods and others.

Assessment appeared in almost all the documents analysed. *Assessment* was coded when the word was explicitly mentioned or, words with similar meaning were used, i.e., Formative exam, Summative exam, Assignment, Assessed course work, Unseen written examinations, Short tests, Feedback on assessed work, and others.

Pedagogy is identified with the module instructor's methods of delivery of the module content. The teaching methods identified were lectures, tutorials, individual feedback or formative feedback. This, therefore, was noted to have direct links to the *Aims, Practice* and *Skills* categories. The *Pedagogy* category was also coded when the teaching mode is mentioned together with learning activities, i.e., practical and laboratory and computing sessions, and others.

Student's learning activities were coded through *Practice* as a main category. The *Practice* category refers to the types of learning activities students had to undertake to learn and acquire knowledge and understanding of the module content, and the skills required for the FY programme. It occurred mostly together with the *Skills*, *Learning Outcomes*, *Pedagogy and Independent Learning* categories. *Practice* was coded when group work, discussion, co-operative working, role playing, independent learning, simulations, problem solving, brainstorming, lab work, workshops, preparing and delivering presentations, and other activities with similar aims were mentioned.

Academic English or language is another main category identified in the analysis. It mostly co-occurred with *Learning Outcomes*, *Pedagogy*, *Practice*, *Skills*, and *Assessment. Academic English* is coded when communications, oral presentations, production of coherent answers to problems, lab reports, written examinations, written coursework, and technical language were mentioned.

The *Aims* category appeared in most of the documents. Aims were identified when the purpose of what the institution is trying to achieve was provided. This category is directly linked to *Knowledge, Pedagogy, Skills* and *Academic English*. Words or phrases which state module objectives were coded, e.g., to develop student's knowledge and competence, to develop skills, and to develop mathematical skills.

Independent Learning is another main category identified, which appeared in almost all the documents analysed. *Independent Learning* was coded when this exact phrase was used, or words and phrases with almost similar meaning, e.g., private study. *Independent Learning* is linked with the *Practice* and *Assessment* categories.

The final main category identified in the analysis is *Knowledge*. This is concerned with the subject-matter and is connected with the module's *Aims* and *Learning Outcomes* for critical thinking skills. *Knowledge* was coded when either knowledge and understanding, or only knowledge, were mentioned together with critical thinking skills. From eighteen documents analysed, nine documents mentioned knowledge and understanding together with critical thinking skills.

Table 7:3 NVivo Coding Scheme and Description

Code	Description	Created By
Academic English	Appropriate academic conventions (language) observed in British higher education in the fields of science engineering.	SP
Aims	Intention of module instructor, purpose of the course, what the institution is trying to achieve by providing it.	SP
Assessment	Assessment of transferable and generic skills and effective communication and analysis and evaluation through written course work, laboratory report, practical laboratory work and written exam.	SP
Confidence	Student's self-assurance resulting from a belief in one’s own ability to achieve things.	SP
Analyse	Data and statistical analysis	SP
Critical Evaluation	An active process of using critical thinking skills to evaluate evidence to find solution, or a conclusion.	SP
Evaluate	Record, analyse and evaluate data; receive, evaluate and reflect on feedback; evaluate and model engineering situations using mathematical principles.	SP
Interpret	Interpret and present data, record and interpret and present information in oral, written and diagrammatic forms with appropriate use of referencing.	SP
Investigative Skills	Experiment and investigation; planning, obtaining and presenting evidence, considering evidence and evaluating.	SP
Making Judgements	Using judgment when reading and presenting statistical summaries.	SP
Predictive Skills	Use mathematical concepts to formulate solutions to solve problems to perform predictive engineering analysis.	SP
Problem-solving	Using mathematical and engineering principles to solve engineering problems.	SP

Code	Description	Created By
Reflection	Dialectical thinking process where a student revisits features of experiences and assign meaning to the experiences to facilitate future action.	SP
Culture	Social and community beliefs/English academic culture	SP
General Transferable Skills	Problem solving, communication skills, mathematical skills, writing skills and computer skills.	SP
Independent Learning	Self-management to prepare for scheduled sessions, follow up work, undertake wider reading or practice, library and online, completion of assessment task and revision.	SP
Intellectual Skills	Problem solving skills and the ability to apply knowledge through discussion, example and practice.	SP
Knowledge	Knowledge and understanding of mathematics that underpins engineering, physics and scientific principles; knowledge is information that can be recalled.	SP
Learning Outcomes	Concerns with the kinds of knowledge that students will be given and the skills they will acquire for a specialised topic where appropriate; student’s achievement rather than instructor's intentions.	SP
Pedagogy	Teaching and learning methods employed by tutors; lectures, small group support sessions etc.,	SP
Practical Skills-Subject Specific	Use and understand mathematical, scientific and technical language; plan and undertake experimental work, explain results and identify potential errors and their likely effect.	SP
Practice	Students’ learning activities through practice such as problem sheets, workshops, lab work, group work, projects, presentations to develop critical thinking skills.	SP
Technical Skills	Creative thinking, computer modelling, attention to detail, mathematical skills, communication skills, computer skills, laboratory skills and teamwork.	SP

7.4 Analysis of Categories and Critical Thinking Skills

The main categories identified in the document analysis have just been described. Critical thinking skills within each category were identified based on these exact words or phrases, or those almost similar in meaning mentioned explicitly in the documents. The analysis focuses on the types of critical thinking skills evident within each category, and on the categories, which have the highest number of critical thinking skills. The full set of critical thinking skills, which were identified is presented in (*Table 7-3*) NVivo Coding Scheme and Description. The detail of the analysis is presented in the following subsections.

7.4.1 Skills Category

The analysis of the *Skills* category includes four main types of skills. Three of the skills identified were *General Transferable Skills, Intellectual Skills, Practical Skills-Subject Specific*, which were explicitly mentioned as separate skills in the learning outcomes in most of the documents. The fourth skill identified was *Technical Skills,* which was drawn from literature on engineering practice.

The data was then manually coded based on words and phrases of similar meanings, using a set of main category codes and subcategories.

The following are the final main skills identified:

i. Technical Skills
ii. General Transferable Skills
iii. Intellectual Skills
iv. Practical Skills-Subject Specific

Technical Skills

We begin *with Technical Skills* because it included most mentions of critical thinking skills. It is associated with computer skills, laboratory work, communication skills, mathematical skills, and teamwork. The types of critical thinking skills associated with *Technical Skills* were *problem solving, analyse, evaluate, interpret, investigative skills,* and *making judgement*. *Problem solving* was most frequently mentioned, followed by *evaluate, and analyse*, and the least mentioned were *interpret, investigative skills* and *making judgment*.

Coding System for *Technical Skills* Category

(i) Problem Solving

(ii) Evaluate

(iii) Analyse

(iv) Investigate

(v) Making Judgements

Problem Solving

Examples:

(i) A2. To develop skills in programming for engineering solutions (CW_X)

(ii) C2. Apply mathematical methods to solve problems (EE_X)

(iii) Effective communication, and data recording, analysis and evaluation are important in presenting the outcomes of laboratory work; application of mathematics and problem solving are generally assessed through unseen written examinations and coursework assignments. (PWA_X)

Evaluate

Examples:

(i) Data recording, analysis and evaluation is developed through practical laboratory and computing sessions. (EFY_X)

(ii) Effective communication, and data recording, analysis and evaluation are important in presenting the outcomes of laboratory work; application of mathematics and problem solving. (PWA_X)

(iii) Problem Solving is generally assessed through unseen written examinations and coursework assignments. (PWB_X)

Analyse

Examples:

(i) Analyse and solve problems using algebraic methods. (IMT_Y)

(ii) Select and use appropriate computer based methods to analyse and present data, reports and other information (PWA_X)

Interpretive Skill, Investigative Skills and Making Judgements

(i) To develop the students' knowledge and competence in applying basic statistical techniques for the extraction, interpretation and presentation of data. (STATS_Y)

(ii) The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role-playing, independent learning, simulation, problem solving, brainstorming, and tutorials. (MT_Y)

(iii) The teaching will emphasise the need for the student to be familiar with the basic terms and methods used in elementary descriptive statistics. In addition, the students will be encouraged to learn to use their judgement when reading and presenting statistical summaries. (STATS_Y)

The analysis of critical thinking skills found within *Technical Skills* shows there is a positive relationship to students learning activities. That is, students' practice in computer programming skills, mathematical modelling, lab work, communication and teamwork leads to exposure to different types of critical thinking skills.

General Transferable Skills

General Transferable Skills is the second commonest type in the *Skills* category. This code was created based on use of the explicit phrase in the documents. When problem solving, communication, mathematical, writing and computer skills were mentioned, these were also interpreted as *Transferable Skills*. These types of *Transferable Skills* were found most in the assessment sections. The types of CTs identified in the general *Transferable Skills* category were *problem solving, evaluate, analyse, critical evaluation* and *reflection. Problem solving* again was noted to be the most mentioned critical thinking skill, and the least mentioned were *critical evaluation* and *reflection*.

Coding System for *General Transferable Skills* Category

(i) Problem Solving
(ii) Evaluate
(iii) Analyse
(iv) Critical Evaluation
(v) Reflection

Problem solving

Examples:

(i)	*You will be assessed through unseen written exams, short tests, assessed coursework in the form of laboratory log books & reports, problems and other set assignments (EFY_X)*
(ii)	*The assessment methods described above place emphasis on your ability to demonstrate the intellectual skills listed here through the production of coherent answers to problems, suitable choices of methods and assumptions. (PWA_X)*

Evaluate

Examples:

(i)	*Assessment 001 assignment assessed by staff testing learning outcomes 1, 2, 4, and contributing 30 % of the final module mark. This will consist of written coursework including the undertaking and evaluation of some detailed calculations and evaluation of simulations. (ET_Y)*
(ii)	*Assessment 001 assignment based upon engineering situations modelling algebraic methods, assessing learning outcomes 1 and 4 and contributing 30 % of the final module mark. This will consist of, some detailed calculations and evaluation of simulations. (MT_Y)*

Analyse

(i)	*Assignment 1 Data analysis + presentation (8% of Coursework module mark). (CW_X)*
(ii)	*Effective communication, and data recording, analysis and evaluation are important in presenting the outcomes of laboratory work; application of mathematics and problem solving are generally assessed through unseen written examinations and coursework assignments. (EFY_X)*

Critical Evaluation and Reflection

Examples:

(i)	*Make a critical evaluation of evidence. (RTS_X)*
(ii)	*Personal reflection on feedback given to you during workshops and tutorials across all subjects. (RTS_X)*

Intellectual Skills

Intellectual Skills were explicitly mentioned in most of the module profiles of University X in the learning outcomes. They were not separately identified in the documents of University Y. They were coded based only on explicit mentions in the document without any additions. The critical thinking skills recognised under *Intellectual Skills* in the analysis were *problem solving*, *analyse, interpret* and *predictive skills*.

Coding System for *Intellectual Skills* Category

(i) Problem
(ii) Analysis
(iii) Interpret
(iv) Predictive Skills

Problem Solving

Examples:

(i) B1. Apply theoretical knowledge to model real-world systems and to <u>solve simple practical</u> <u>problems</u> in statics and in linear and rotational dynamics and simple field theory. (MS_X)

(ii) B1. Apply theoretical knowledge to <u>solve simple practical problems</u> in energy transport and exchange. (EP_X)

Analysis, Interpretive and Predictive Skills

Examples:

(i) <u>Interpret</u> and <u>analyse</u> a range of information beyond mere description. (EES_X)

(ii) Analyse and <u>predict</u> the behaviour of simple logic circuits and electronic devices. (EE_X)

Practical Skills Subject-Specific

Practical Skills Subject-Specific were also associated with critical thinking skills, and were clearly stated in the learning outcomes of the module profiles from University X. They did not appear explicitly in the profiles of University Y. Within this category *Problem solving* skills were identified in the document, while investigative skills and predictive skills were identified based on words and phrases with almost similar meaning.

Coding System for *Practice Skills-Subject Specific Skills* Category

(i) Problem Solving
(ii) Interpretive Skills
(iii) Predictive Skills

Problem Solving, Investigative Skills and Predictive Skills

Examples:

> *(i) Make realistic estimates of the answers to problems. (PWA_X)*
>
> *(ii) Plan and undertake experimental work, explain results and identify potential errors and their likely effect. (EFY_X)*

The analysis of the skills categories and the critical thinking skills identified within them shows that *Technical Skills* have the most mentions of critical thinking skills, followed by *General Transferable Skills, Intellectual Skills*, and last *Practical Skills-Subject Specific*. Based on the CTs identified in these skills categories as shown in *Figure 7:1*, it is apparent that *problem solving* is the dominant critical thinking skill in all four skills categories, followed by *analyse*, and *evaluate*. *Investigative Skills* were mentioned in the general programme profile of University X, (EFY_X), whereas, *Predictive Skills* only appeared in the English support modules, (PWA_X) and (PWA_B).

Apart from this, the analysis shows that *Investigative Skills* only appeared in *Practical Skills-Subject Specific* and *Technical Skills*. The rarely mentioned *predictive skills* only appeared in *Intellectual Skills* and *Practical Skills-Subject Specific*. *Interpret* is another rarely mentioned critical thinking skill which appeared in *Intellectual Skills* and *Technical Skills*. This shows that the FY programme incorporates the *investigative, predictive*, and *interpret critical thinking skills* in a specific context which relates to mathematical skills, (MT_Y) and (STATS_Y), as in *interpreting* data. On the other hand, the English Language for Engineers 'module, (EES_X), was concerned with the interpretive critical thinking skill in terms of interpreting and analysing a range of information from resources.

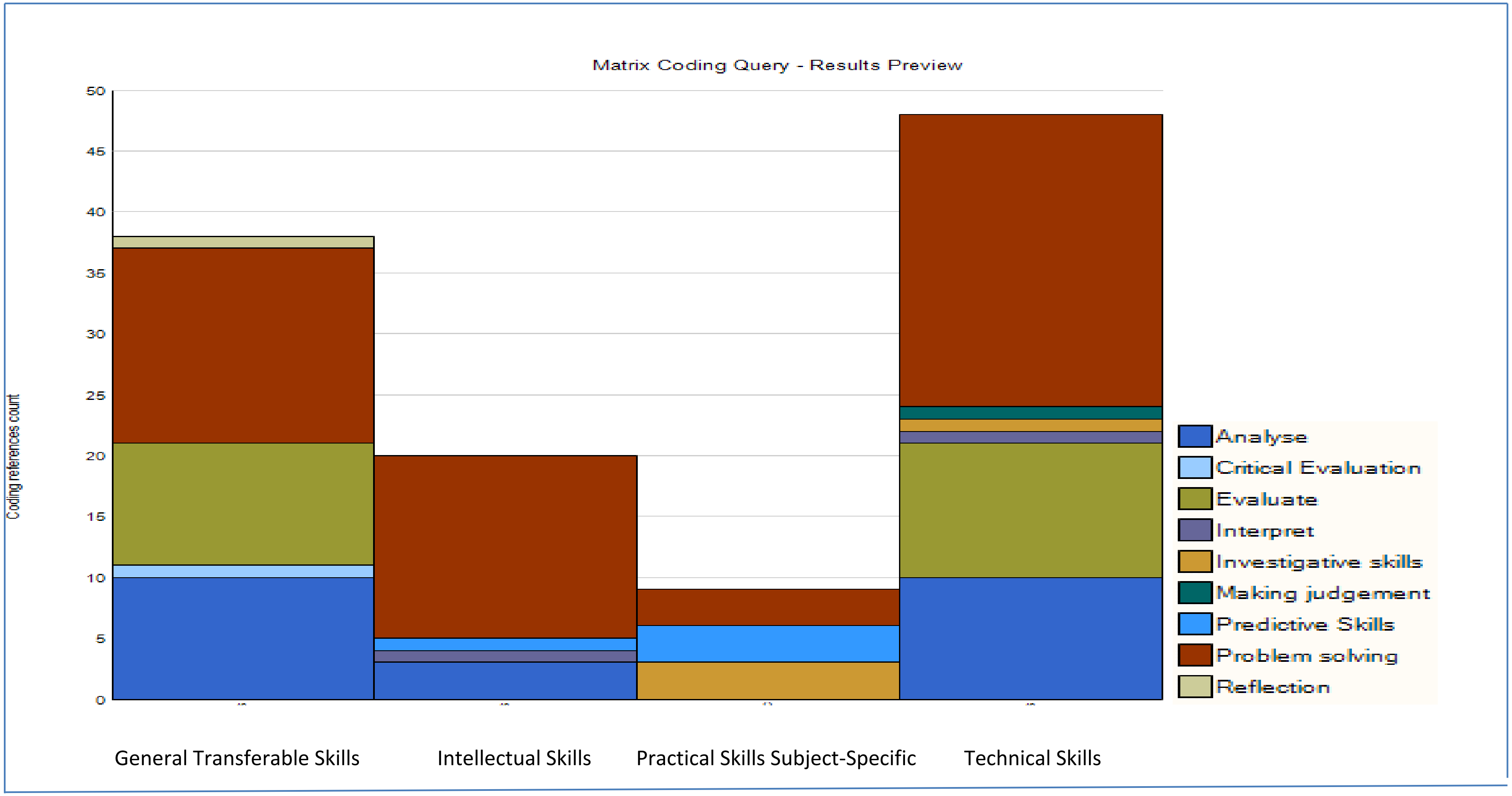


Figure 7:1 Types of Critical Thinking Skills Identified in Skills Category

The distribution of critical thinking skills across the four skills categories is shown in *Table 7:4* Skills Categories and Types of Critical Thinking Skills Identified. It can be seen that *Practical Skills-Subject Specific* has an equal number of three types of critical thinking skills; *Predictive Skills, Investigative Skills* and *Problem Solving*. These three are practical skills used in planning, experimenting and explaining results, and also identifying potential errors and the implications of an action.

Table 7:4 Skills Categories and Types of Critical Thinking Skills Identified

Skills Category	**Types of Critical Thinking Skills**									
	A	**CE**	**E**	**I**	**IVs**	**MJ**	**PDs**	**PS**	**R**	**Total**
General Transferable Skills	10	1	10	0	0	0	0	16	1	38
Intellectual Skills	3	0	0	1	0	0	1	15	0	20
Practical Subject-Specific Skills	0	0	0	0	3	0	3	3	0	9
Technical Skills	10	0	11	1	1	1	0	24	0	48

Key:

A – Analyse CE – Critical Evaluation E – Evaluate I – Interpret

IVs – Investigative Skills MJ – Making Judgment PDs – Predictive Skills

PS – Problem Solving R - Reflection

Overall analysis of the types of skills exposed in the Engineering Foundation Year Programme, shows that CTs were largely incorporated in *Technical Skills* and least common within *Practical Subject-specific Skills*, which focused on engineering content. This indicates that at foundation level, students acquiring basic Technical Skills than to subject-based CTs.

7.4.2 Learning Outcomes Category

The *Learning Outcomes* category is concerned with the kinds of knowledge students will be given and the skills they will acquire for a specialised topic where appropriate, conceptualised as students' achievement rather than instructor' aims. The types of critical thinking skills identified with the learning outcomes were *problem solving, analyse, evaluate, investigative skills, predictive* *skills, interpretive skills, reflection*, and *critical evaluation*. *Problem solving* has the highest number of references coded followed by *analyse, evaluate, investigative skills, predictive skills, interpretive skills, reflection* and *critical evaluation.*

Coding System for *Learning Outcomes* Category

(i) Problem Solving
(ii) Analyse
(iii) Evaluate
(iv) Interpret
(v) Predictive Skills
(vi) Investigative Skills
(vii) Reflection
(viii) Critical Evaluation

Problem Solving

Examples:

(i) B1. Apply theoretical knowledge to solve simple practical problems in energy transport and exchange. (EP_X)
(ii) S1. Solve simple mathematical problems based on handling numbers and elementary algebraic techniques. (MT_Y)
(iii) B2. Use scientific principles in the development of solutions to simple real-world problems. (PWA_X)

Analyse

Examples:

(i) Record, analyse and evaluate data effectively. (CW_X)
(ii) Select and use appropriate computer based methods to analyse and present data, reports and other information. (PWA_X)

Evaluate

Examples:

(i) Record, analyse and evaluate data. (PWB_X)
(ii) How to receive, evaluate and reflect on feedback on your progress in HE. (RTS_X)

Investigative and Predictive Skills

Examples:

(i) *Plan and undertake experimental work, explain results and identify potential errors and their likely effect. (EFY_X)*

(ii) *Analyse and predict the behaviour of simple logic circuits and electronic devices. (EE_X)*

Interpretation, Reflection and Critical Evaluation

Examples:

(i) *S1. Record, interpret and present information in oral, written and diagrammatic forms with appropriate use of referencing. (SCS_Y)*

(ii) *Organise your language learning effectively: reflect on your progress; set study targets and learn how to plan and organise your own learning schedule. (EES_X)*

(iii) *Make a critical evaluation of evidence. (RTS_X)*

The *Learning Outcomes* category has the highest number of critical thinking skills references after the Skills Category. The types of critical thinking skills which had the lowest number of references coded were *interpret, reflect* and *critical evaluation*. *Reflection* appeared in the learning outcomes for the English language for engineers' module, (EES_X), directed towards reflecting on study progress and self-planning in developing independent learning. The *interpreting* skill found in the Learning Outcomes for Study and Communication skills (SCS_Y) was focused on the interpreting of information in oral and written language. (RTS_X) as a generic skills module for FY expects students to apply *critical evaluation* of evidence, which could include resources for other subject-specific modules i.e., engineering principles, electronics and others.

7.4.3 Assessment Category

The analysis found that the *Assessment* category paid significant attention to some critical thinking skills. Critical thinking skills were mainly tested within the *Transferable* and *Technical Skills* categories, and were reflected in assessments of language use, lab reports, practical laboratory work and written exams. The critical thinking skills which were most tested were *problem solving*, followed by *evaluate, analyse* and *reflection.*

Coding System for *Assessment* Category

(i) Problem Solving
(ii) Evaluate
(iii) Analyse
(iv) Reflection

Problem Solving

Examples:

(i) You will be assessed through unseen written exams, short tests, assessed coursework in the form of laboratory logbooks & reports, <u>problems</u> and other set assignments. (EFY_X)

(ii) The assessment methods described above place emphasis on your ability to demonstrate the intellectual skills listed here through the production of <u>coherent</u> <u>answers to problems</u>, suitable choices of methods and assumptions. (PWB_X)

Evaluate

Examples:

(i) Assessment 001 assignment assessed by staff testing learning outcomes 1, 2, 4, and contributing 30 % of the final module mark. This will consist of written course work including the undertaking and <u>evaluation</u> of some detailed calculations and <u>evaluation</u> of simulations. (ET_Y)

(ii) Effective communication, and data recording, analysis and <u>evaluation</u> are important in presenting the outcomes of laboratory work; application of mathematics and problem solving are generally assessed through unseen written examinations and coursework assignments. (PWA_X)

Analyse

Examples:

(i) Assignment 1 <u>Data analysis</u> + presentation (8% of Coursework module mark). (CW_X)

(ii) Effective communication, and data recording, <u>analysis</u> and evaluation are important in presenting the outcomes of laboratory work; application of mathematics and problem solving are generally assessed through unseen written examinations and coursework assignments. (PWA_X)

Reflection

Example:

(i) Personal reflection on feedback given to you during workshops and tutorials across all subjects. (RTS_X)

The analysis shows, that while *problem solving* was the most mentioned critical thinking skill, it was not generally clear how it would be tested. In comparison, the critical thinking skill evaluate was directly related to engineering skills such as laboratory work, evaluating the approach in solving mathematical problems, or evaluation of simulations. In these cases it was clear that evaluate was closely linked to data analysis.

7.4.4 Pedagogy Category

The *Pedagogy category* is concerned with the teaching and learning methods employed by tutors. It was analysed to determine the types of critical thinking skills expected to be developed in the FY programme through lectures, workshops, tutorials, lab work and other activities. It was noted the types of critical thinking skills expected were mostly *problem solving, analyse, evaluate, investigative skills* and *making judgement*.

Coding System for *Pedagogy* Category

(i) Problem Solving
(ii) Analyse
(iii) Evaluate
(iv) Investigative Skills
(v) Making Judgements

Problem Solving

Examples:

(i) Managing own learning is learnt, rather than taught, through the requirement to organise your private study and to meet the deadlines for submission of work; problem solving is a theme you will find running throughout the course as is application of mathematics. (EFY_X)

(ii) The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role-playing, independent learning, simulation, problem solving, brainstorming, and tutorials. (MT_Y)

Analyse and Evaluate

Example:

(i) Data recording, analysis and evaluation is developed through practical laboratory and computing sessions. (PWB_X)

Investigative Skills and Making Judgements

Examples:

(i) The teaching will emphasise the need for the student to be familiar with the basic terms and methods used in elementary descriptive statistics. In addition, the students will be encouraged to <u>learn to use their judgement</u> when reading and presenting statistical summaries. (STATS_Y)

(ii) The practical sessions will be used to encourage students to develop their <u>investigative skills</u> and develop their understanding of the theoretical principles from the lectures. (ET_Y)

Problem solving was explicitly stated in the general module profile (EFY_X) of University X as a theme running throughout the course. However, this was not clear in the FY programme of University Y, partly because not all relevant documents were available. Nevertheless, one of the module profiles of University Y, (MT_Y) indicated *problem solving* will be adopted together with other CTs such as *investigative skills*. It was noted that *investigative skills* and *making judgments* have only limited exposure in the statements on pedagogy of the FY programmes.

7.4.5 Practice Category

The *Practice* category relates to students' learning activities through practice such as problem sheets, attending workshops, lab work, and group work to develop their critical thinking skills. Most of the critical thinking skills were identified together with the *Pedagogy* category as the statements were mostly combined. The *Practice* category shows *problem solving* is the most referenced critical thinking skill, and the remaining ones were *analyse, evaluate, investigative skill* and *making judgements*.

Coding System for *Practice* Category

(i) Problem Solving
(ii) Analyse
(iii) Evaluate
(iv) Investigative
(v) Making Judgements

Problem Solving

Examples:

(i)	*Each module will help you to develop problem solving skills and the ability to apply your knowledge through discussion, example and practice. (EFY_X)*
(ii)	*The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role playing, independent learning, simulation, problem solving, brainstorming, and tutorials. (MT_Y).*

Analyse and Evaluate

Example:

(i)	*Data recording, analysis and evaluation is developed through practical laboratory and computing sessions. (PWA_X)*

Investigative Skills and Making Judgements

Examples:

(i)	*The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role playing, independent learning, simulation, problem solving, brainstorming, and tutorials. MT_Y)*
(ii)	*The practical sessions will be used to encourage students to develop their investigative skills and develop their understanding of the theoretical principles from the lectures. (ET_Y)*
(iii)	*The teaching will emphasise the need for the student to be familiar with the basic terms and methods used in elementary descriptive statistics. In addition the students will be encouraged to learn to use their judgement when reading and presenting statistical summaries. (STATS_Y)*

Analysis of the *Practice* category shows that students should expect opportunity to practice and develop critical thinking skills such as *problem solving* through application of knowledge, group discussion, examples and practice sheets. However, it was apparent from the analysis that students were only offered limited practice on *investigative skills,* and *making judgements*, since these skills appeared only in three from the eighteen modules analysed. The modules which have clearly stated the application of *investigative skills* and *making judgement* were (MT_Y), (ET_Y) and (STATS_Y), offered by University Y.

7.4.6 Academic English Category

The *Academic English category* is concerned with academic conventions observed in British higher education in the fields of science and engineering. It was identified in the analysis when language, communications, oral or, written examinations, or laboratory reports were mentioned in connection with critical thinking. The types of critical thinking skills identified in the Academic English category are *problem solving*, which was the most referenced, followed by *analyse, evaluate, interpret and reflection.*

Coding System for *Academic English* Category

(i) Problem Solving
(ii) Analyse
(iii) Evaluate
(iv) Interpret
(v) Reflection

Problem Solving

Examples:

> *(i) The assessment methods described above place emphasis on your ability to demonstrate the intellectual skills listed here through the <u>production of coherent answers to problems</u>, suitable choices of methods and assumptions. (PWA_X)*

Analyse and Evaluate

Examples:

> *(i) Effective <u>communication</u>, and data recording, <u>analysis</u> and <u>evaluation</u> are important in <u>presenting the outcomes of laboratory work</u>; application of mathematics and problem solving are generally assessed through unseen <u>written examinations</u> and <u>coursework assignments</u>. (PWB_X)*
>
> *(ii) This will consist of <u>written coursework</u> or <u>laboratory report</u>, including the undertaking and <u>evaluation</u> of practical laboratory work, some detailed calculations and <u>evaluation</u> of simulations. (ET_Y)*

Interpretation and Reflection

Examples:

(i) S1. Record, interpret and present information in oral, written and diagrammatic forms with appropriate use of referencing. (SCS_Y)
(ii) Organise your language learning effectively: reflect on your progress; set study targets and learn how to plan and organise your own learning schedule. (EES_X)

The *Academic English* category is identified with critical thinking skills mostly in oral and written communications. It was not evident whether the communications mentioned in the document includes other language use such as reading. In addition, it was apparent in the analysis that most of the statements found in the academic English language modules taught at University X, (PWA_X) and (PWB_X), pertaining to critical thinking were similar to the general FY descriptions (EFY_X), as both refer to generic skills which are applicable in most of the modules.

7.4.7 Aims Category

The *Aims* category outlines what the institution aims to achieve by providing the modules in the engineering FY programme. It is analysed to determine to what extent critical thinking skills were given preference in the FY programme. Out of eighteen documents analysed three module profiles, (IMT_Y), (ET_Y), and (PROJ_Y), did not explicitly state any *Aims*, but only included *Learning Outcomes*. However, a detailed description of the module was given in the Module Overview section, which partly included the aims. From the analysis it was evident that only two critical thinking skills were mentioned in the module profiles; *problem solving and interpret*.

Coding System for *Aims* Category

(i) Problem Solving
(ii) Interpret

Problem Solving

Examples:

(i) Develop skills in programming for engineering solutions.(CW_X)
(ii) Starting from basic rules, definitions and axioms, to enable you to build a working toolbox of mathematical techniques, concepts and facts for solving problems in pre-calculus mathematics. (MTA_X)
(iii) To emphasise the meaning and purpose of these techniques and their use in solving Engineering and Physics problems. (MTB_X)
(iv) Introduce you to problem solving and solution checking techniques. (RTS_X)

Interpret

Example:

(i) To develop the students' knowledge and competence in applying basic statistical techniques for the extraction, interpretation and presentation of data. (STATS_Y)

The frequent mention of *problem solving* in the *Aims* category shows that the most likely critical thinking skill students are expected to learn and develop in the FY is the *problem solving* skill. This analysis also supports that of the *Pedagogy* category, which has *problem solving* as the most mentioned critical thinking skill. The interpret skill is another critical thinking skill closely linked with data analysis, and is part of the technical skills required in engineering.

7.4.8 Independent Learning Category

Independent Learning was mentioned in almost all of the modules analysed as a theme running through the programme. However, it was only referenced to five times with CTs. The critical thinking skills associated with the Independent Learning category were *problem solving and investigative skills*. This category will be included in the analysis, but the findings will not be discussed in the discussion chapter because it is not relevant to the research project.

Coding System for the *Independent Learning* Category

(i) Problem solving
(ii) Investigative skills

Problem Solving

Examples:

(i)	*The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role playing, independent learning, simulation, problem solving, brainstorming, and tutorials. (MT_Y)*
(ii)	*Managing own learning is learnt, rather than taught, through the requirement to organise your private study and to meet the deadlines for submission of work; problem solving is a theme you will find running throughout the course as is application of mathematics. (EFY_X)*

Investigative Skills

Example:

(i)	*The strategies adopted will vary and will include some if not all of the following: investigation, group work, discussion, co-operative working, role playing, independent learning, simulation, problem solving, brainstorming, and tutorials. (MT_Y)*

The *Independent learning* category is closely related to the *Practice* category and it is evident from the analysis that students are expected to learn and develop problem solving and investigative skills through self-study and self-planning.

7.4.9 Knowledge Category

Knowledge is concerned with the understanding of mathematical concepts and engineering principles that underpin engineering, and it refers to knowledge that can be recalled. Critical thinking skills which were associated with *Knowledge* were *problem solving, evaluate, interpret* and *reflection*.

Coding System for the *Knowledge* Category

(i) Problem Solving
(ii) Evaluate
(iii) Interpret
(iv) Reflection

Problem Solving

Examples:

> *(i) Starting from basic rules, definitions and axioms, to enable you to build a working toolbox of mathematical techniques, concepts and facts for <u>solving problems</u> in pre-calculus mathematics. (MTA_X)*
>
> *(ii) A1. How to approach <u>problem solving</u> in a structured way. (RTS_X)*

Evaluation, Interpretation and Reflection

Examples:

> *(i) How to receive, <u>evaluate</u> and <u>reflect</u> on feedback on your progress in HE. (RTS_X)*
>
> *(ii) To develop the students' knowledge and competence in applying basic statistical techniques for the extraction, <u>interpretation</u> and presentation of data. (STATS_Y)*

It was evident in the *Knowledge* category that the, Route to Success module (RTS_X) had more reference to critical thinking skills compared to other modules, such as, maths (MTA_X) and statistics (STATS_Y).

Table 7:5 Overview of Critical Thinking Skills in the Main (Non-Skill) Categories

Main Categories	**Critical Thinking skills**									**Total**
	A	**CE**	**E**	**I**	**IVs**	**MJ**	**PDs**	**PS**	**R**	
Academic English	3	0	4	1	0	0	0	7	1	15
Aims	0	0	0	1	0	0	0	8	0	9
Assessment	4	0	7	0	0	0	0	8	1	20
Confidence	0	0	0	0	0	0	0	0	0	0
Culture	0	0	0	0	0	0	0	0	0	0
Independent Learning	0	0	0	0	1	0	0	4	0	5
Knowledge	0	0	1	1	0	0	0	2	1	5
Learning Outcomes	10	1	7	2	4	0	4	26	2	56
Pedagogy	3	0	3	0	2	1	0	7	0	16
Practice	3	0	3	0	2	1	0	7	0	16
TOTAL	23	1	25	5	9	2	4	69	5	

Key:
A – Analyse CE – Critical Evaluation E – Evaluate I – Interpret IVs – Investigative Skills
MJ – Making Judgement PDs – Predictive Skills PS – Problem Solving R – Reflection

The overall analysis shown in *Table 7:5* clearly shows the types of critical thinking skills, which are made explicit in the FY programme. Of the nine types of CTs; *problem solving* was the most referenced, followed by *evaluate, analyse, investigative skills, interpret, reflection, predictive skills, making judgements* and *critical evaluation*. Based on the types of critical thinking skills identified, the *Learning Outcomes* category has the greatest number of references to CTs followed by the Assessment category. These two categories are clearly connected. The Learning Outcomes show the kinds of knowledge and skills students will be expected to achieve at the end of the FY programme, and in a valid assessment the students will be tested on what has been taught. Assessment could also be a learning tool for skills. Furthermore, because the critical thinking skills are intended to be tested, this raises the importance of their inclusion in the pedagogical and practice activities.

On the other hand, the *Academic English* category also recorded a substantial amount of critical thinking skills. *Problem solving* is referenced the most in connection with language use through communication, oral and written, lab work, and in the written assessment. This indicates how language is expected to play a role in students learning and developing the critical thinking skills intended for the foundation year.

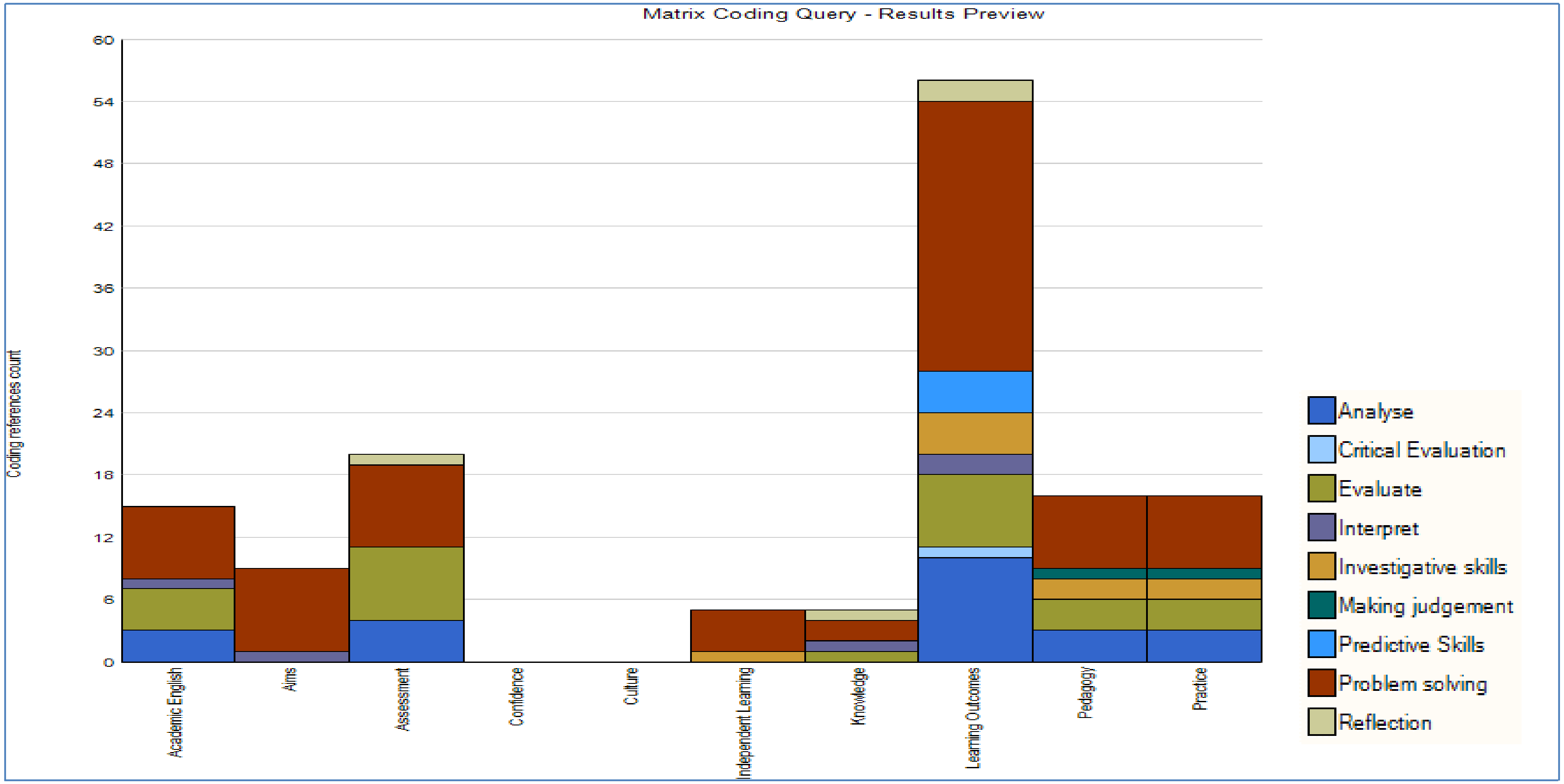


Figure 7:2 Critical Thinking Skills within Non-Skill Categories

As for the distribution of the types of critical thinking skills within the categories as shown in (*Figure 7-2 on p 210)*. It is noted that *Confidence* and *Culture* were not associated with any CT skills. From ten categories identified in the analysis, eight have recorded *problem solving* as the main critical thinking skills, followed by *analyse and evaluate. Predictive skills* and *critical evaluation* were only mentioned in the Learning Outcomes category. The Aims and Independent Learning categories only have a combination of two types of critical thinking skills which were problem solving and interpret, and problem solving and investigative skills. The rest of the categories have more than three types of critical thinking skills recorded in the module profiles.

7.5 Analysis of Modules and Critical Thinking Skills

The following overview determines which critical thinking skills were given preference in designing the modules. Besides that, the types of skills made explicit in the modules will also be analysed. The analysis was conducted using Matrix coding in NVivo 11 software. The types of critical thinking skills were coded based on exact words or phrases, and words or phrases with almost similar meaning stated explicitly in the modules.

Table 7:6 Critical Thinking Skills Identified in the EFY Modules

Module	A	CE	E	I	IVs	MJ	PDs	PS	R	TOTAL CTs
CW_X	3	0	2	0	0	0	0	6	0	11
EE_X	0	0	0	0	0	0	1	2	0	3
EES_X	1	0	0	1	0	0	0	0	1	3
EFY_X	4	0	3	0	1	0	1	9	0	18
EP_X	0	0	0	0	0	0	0	2	0	2
ET_Y	0	0	2	0	1	0	0	0	0	3
IMT_Y	1	0	3	0	0	0	0	0	0	4
IT_Y	0	0	0	0	0	0	0	0	0	0
MS_X	0	0	0	0	0	0	0	2	0	2
MT_Y	0	0	0	0	1	0	0	2	0	3
MTA_X	0	0	0	0	0	0	0	3	0	3
MTB_X	0	0	0	0	0	0	0	3	0	3
PWA_X	4	0	3	0	1	0	1	9	0	18
PWB_X	4	0	3	0	1	0	1	9	0	18
PROJ_Y	0	0	0	0	1	0	0	0	0	1
RTS_X	0	1	1	0	0	0	0	3	2	7
SCS_Y	0	0	0	1	0	0	0	0	0	1
STATS_Y	0	0	0	1	0	1	0	0	0	2

Key:

A – Analyse   CE – Critical Evaluation   E – Evaluate   I – Interpret   IVs – Investigative Skills

MJ – Making Judgement   PDs – Predictive Skills   PS – Problem Solving   R – Reflection

The analysis shows, (*Table 7:6*), that three of the eighteen modules analysed have the highest numbers of critical thinking skills. The three modules from University X were (EFY_X), a general specification of the FY programme, (PWA_X) and (PWB_X), the language pathway modules. All these three modules have equal numbers of eighteen critical thinking skills recorded. It was noted from the analysis that the statements with critical thinking skills identified in documents were mostly similar, as the (EFY_X) is a general specification of the FY programme, and the others were found in general modules on academic English. Another module, which has a substantial numbers of critical thinking skills was (CW_X) a coursework module at University X. Coursework requires students to incorporate all the knowledge and skills learnt from the module to be presented in a coherent answer for assessment, which could be the reason for a high number of critical thinking skills being mentioned in the module.

7.6 Conclusion

Overall, from the eighteen modules analysed, seventeen modules have incorporated and explicitly stated CTs in their documents. In addition, the analysis shows that from the nine types of CTs identified, problem solving is the dominant skill in the EFY programme at the University of X, whereas at the University of Y, evaluate and interpret were the dominant skills. Making judgements only appeared in the (STATS_Y) module. The result shows the EFY modules overall purpose and what the EFY programme try to achieve. It is clear that the institutions of both University X and University Y have designated CTs as one of the core skills in their programme for EFY students.

Chapter 8 Discussion

8.1 Introduction

The purpose of this exploratory research was to find out how students learn and develop critical thinking skills in the Engineering Foundation Year (EFY) programme. Students' understanding and attitudes towards critical thinking skills were investigated longitudinally, taking account of their first language, previous learning experiences, and their cultural background. To investigate the relationship between teaching and learning practice within the programme, and the development of critical thinking skills, the students and module instructors were asked to what extent there were opportunities to practise the skills in the programme, and what types of critical thinking skills students were exposed to during the foundation year. In addition, faculty's goals for students' Critical Thinking skills (CTs) were investigated in two ways, firstly, by analysing module instructors' definition of critical thinking skills to determine whether this influenced their pedagogical choices. Secondly, by analysing module profiles and other local course documents to check whether CTs were evident in the documents, and, if yes, what types of skills were given preference in the foundation year.

The engineering FY was chosen for this research because it is a pathway programme offered to both UK and overseas students who did not meet the requirements for direct entry into a bachelor's degree in engineering. The FY offers opportunities for students to prepare themselves with the relevant knowledge, technical language and academic skills required for undergraduate study in the UK, and critical thinking skills are one of the most required skills students are expected to demonstrate. Therefore, the research was interested in finding out how the FY students from diverse backgrounds learn and develop the required critical thinking skills. The findings from this research would determine how far there are variations and similarities among the different groups of students in their CTs, and how the faculty gauge the differences, and supports the similarities to enhance students' learning experiences. In addition the findings will provide a primary source of information directly from the students, which the faculty could utilise to improve or revise the foundation year syllabus or programme to provide better opportunities for them to learn and develop critical thinking skills as engineers with relevant intellectual traits, and high levels of professional and ethical conduct.

8.2 Summary of Data Source

The research adopted qualitative research methods to collect and analyse the data. Three types of source data were collected, which were three sets of students' semi-structured interviews, one set of module instructors' semi-structured interviews, and FY programme course documents. Student participants were interviewed at three different stages of their study, first, at the beginning of semester two of their FY (2014-15), second, immediately after their end of FY examinations, and third at the beginning of semester two of the first year (2015-16) of their engineering undergraduate programme. The data was analysed thematically with a combination of manual analysis and NVivo Pro 11 software. The interview data was analysed manually because the conceptualisations of CTs, and other issues surrounding them were too complex to use a software programme to code using exact, or almost similar meaning words or phrases to capture the meaning. On the other hand, the NVivo software was useful to analyse the course documents, for the words and phrases used to describe CTs could be coded thematically based on what explicitly appears on the documents, and this helped in avoiding any missed information from the documents. In addition, 'Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering', was used to cross-match the students' and module instructors' accounts with course documents. The details of the blended model were presented in (*Chapter 3, Table 3:3 on p 52-54*). The details of the data sources, participants' types of data analysis and tools used are shown in (*Table 8:1)* below.

Table 8:1 Data Sources and Data Analysis Approach

	Data Source			
	Semi-structured Interviews		Module Profiles	
	Students	Module Instructors	University X	University Y
	International SS01_M_I_Bahrain SS02_M_I_Libya European SS06_M_EU_Greece (with listening disability) SS07_M_EU_Poland SS08_M_EU_Latvia SS09_M_EU_Cyprus UK and USA SS10_M_UK SS11_F_UK SS12_M_UK (mature student without technical background) SS13_M_USA (mature student with technical experience)	University X MI01_MTX_F_NN MI02_CP_M_N MI03_WS_M_N MI04_EP_F_NN MI05_MS_M_N MI06_PWA_F_N MI07_EEX_M_N MI08_EES_F_N University Y MI09_MTY_F_N MI10_EEY_M_N	EFY_X EES_X PWA_X PWB_X EE_X EP_X MS_X MTA_X MTB_X RTS_X CW_X	ET_Y IMT_Y PROJ_Y IT_Y MT_Y STATS_Y SCS_Y
Analysis approach and Tool	Thematic and manual		Thematic and NVivo Pro 11 software	

The discussion of the findings of the research is guided by the research questions and presented in the following section.

8.3 Summary and Discussion of the Research Findings

The research is focused on students' development of critical thinking skills (CTs), teaching and learning practice within the engineering foundation programme, and faculty's goals for students' critical thinking skills. Discussion of the findings is organised according to the research questions and related to the Blended Framework of Critical Thinking Skills for Foundation Year Engineering.

8.3.1 Students' perceptions and attitudes towards critical thinking skills

Research Question 1: **What are Engineering Foundation Year students' perceptions and attitudes towards critical thinking skills at the beginning and at the end of the programme?**

The first question explores how students define critical thinking skills (CTs) at the beginning of their foundation year based on their previous knowledge and their own understanding, and at the end of the programme based on their Engineering Foundation Year (EFY) experience. The question also explores students' attitudes towards CTs at the beginning, and at the end of the programme.

i. Students' Responses: Stage One Interview – mid foundation year

The students who participated in the research were from diverse backgrounds and different countries: Bahrain, Libya, Greece, Poland, Latvia, Cyprus, United Kingdom (UK) and United States (USA). Their initial perceptions and conceptions of CTs expressed in the Stage One interview show a whole range of ideas, which could be categorised as CTs in general and academic context. *Problem solving* was the most frequently mentioned interpretation by six from the ten students, followed by *scientific thinking*, *self-correcting* and *critical evaluation* mentioned by two students, one each from the European and international groups. Critical thinking was also perceived as *conscious thinking*, *productive thinking*, *making clear judgement*, *identifying mistakes and independent thinking.*

However, students' definitions of CTs from the different groups were not the same. The UK educated group's view on CTs was *problem solving*, whereas the European group added other interpretations; *self-correcting, objective evaluation, scientific thinking, conscious thinking, making clear judgement*, and *productive thinking*. The international group on the other hand, interpreted CTs as *critical evaluation*, *analysing*, and *synthesising*. The European group were able to produce the largest number of interpretations of CTs. Based on the definitions, there were noticeable differences between the UK group and the other two groups, in which *problem solving* was dominant in the UK group.

Some other individual differences emerged within the whole group. One of the two mature students (SS13_M_USA), defined CTs as *independent thinking*. For this mature student, having independent thought was more relevant due to his previous technical experience in the workplace involving self-reliance, and making decisions. As for the student with a hearing disability (SS09_M_Cyprus), for him CTs were *identifying mistakes*. This definition could be due to his hearing disability, in that he tended to focus more on his visual ability to identify mistakes.

Based on the Stage One interviews, students' perceptions of CTs included both general skills and skills specific for engineering. However, when analysed with the research Blended Conceptual Framework for CTs, (*Table 8:2 on p 220*), it becomes evident that students' initial understanding of CTs could more easily be related to *Dewey's Logical Considerations (DLC),* than to the *Engineering Reasoning Model of Paul, Niewoehner and Elder (PNE)* and the *Conceive Design Implement Operate (CDIO)* engineering syllabus. Students' definitions were closer to DLC, insofar as they referred to general thinking skills; *abstract thinking, concrete and scientific thinking*, and *bringing a closure*, or *making judgements*. Nevertheless, it was apparent that some students were integrating their previous scientific knowledge as high school science students to define CTs which related to PNE and CDIO, particularly in *applying intellectual traits*, *problem solving*, and *system thinking in engineering context*. These students belonged mainly to the UK/USA and European group.

Table 8:2 Students' Conception of Critical Thinking Skills Compared with Blended Conceptual Framework for Critical Thinking for Foundation Year Engineering – Stage One

Stage One Interview	**Blended Conceptual Framework for Critical Thinking for FY Engineering**		
	Dewey's Logical Considerations (DLC)	Paul, Niewoehner and Elder (PNE)	CDIO
Problem solving	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (ii)	Elements of Thought	2.1 Analytical reasoning and Problem Solving (2.1.1)
Critical evaluation	Analysis Complete Act of Thought (ACAT) - (i and v)	Elements of Thought and Intellectual Traits (Humility)	2.4 Attitudes, Thought and Learning (2.4.4, 2.4.5)
Making clear judgements	Judgement: Interpretation of Facts (JIF) - (ii and iii)	Intellectual Traits (Confidence in Reason)	2.3 System Thinking (2.3.4)
Thinking independently		Intellectual Traits (Autonomy)	
Scientific thinking	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (iv)		2.2 System Thinking (2.2.1)
Conscious thinking		Intellectual Traits (Humility)	2.4 Attitudes, Thought and Learning (2.4.5)
Productive thinking	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (i, ii and iv)		
Analysing and synthesising	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (iv)		
Self-correcting	Thought: Abstract, Concrete, Empirical and Scientific (TACES) – (i)	Intellectual Traits (Humility, Courage)	
Objective evaluation on information and environment	Judgement: Interpretation of Facts (JIF) – (i)		
Identifying mistakes	Analysis Complete Act of Thought (ACAT) – (i)		

Students' attitudes towards CTs at the beginning of FY were mixed, from a sense of their importance, uncertainties about them, satisfaction, and confidence to frustration. However, a majority believe CTs are important at the foundation level. They were willing to describe CTs in FY as, 'extremely important' (SS09_M_Greece), 'it's key' (SS10_M_UK), and, 'very important', (SS01_M_Bahrain). Besides that, students also expressed satisfaction, 'enjoy', 'benefitted', 'thoroughly happy', (SS06_M_Greece), and, 'I'm trying to take as much from the foundation year, this year as much as I can', (SS07_M_Poland), and also confidence, 'at the moment I don't feel that I'm failing at all', (SS08_M_EU_Latvia). This may indicate that their transition from the high school to university setting in the UK academic environment was helping them in acquiring the required academic skills including CTs in their FY.

Based on the majority of their responses, there were no clear differences between the groups in their attitudes towards CTs. However, there was some sense of frustration among three students which was not directly linked to CTs, more to the FY programme overall:, 'I can honestly feel myself becoming demoralised, demotivated by that time passing', (SS13_M_USA): 'it's like wasting a lecture at the start of the year. I'd rather not sit in that lecture, and do the work over the summer and make sure that I know it. Or, at least should know it and would have a lecture to cover another harder content', (SS12_M_UK), and 'I wish I didn't do well because I have like three modules in Physics and one Maths, but the English Pathway students have less pressure', (SS02_M_Libya). For the mature students, (SS12_M_UK) and (SS13_M_USA), they felt some modules were repetitive and a waste of time, since they already had college/bachelor qualifications respectively from their previous education. As for (SS02_M_Libya), his frustration was based on the language support class, which he found very useful, but it was only offered to those who did not meet the university English Language requirement, unlike him. Although, these responses were not directly related to CTs, they helped in understanding students' confidence levels. For example, (SS13_M_USA), (SS12_M_UK) and (SS02_M_Libya) had not developed the *Intellectual Traits* of PNE as in *Intellectual Perseverance and Confidence* (see *Figure 3:1 on p 46*). Developing these *Intellectual Traits* takes time and training, and it would be interesting to see how far they would develop in the undergraduate engineering course.

ii. Student Responses: Stage Two Interview – immediately after Foundation Year final examination

Stage Two interview data showed that, there was a small change in students' perceptions and attitudes when applying thinking about CTs and examination conditions, which were directly related to the *Knowledge* and *Practice* categories. In examination conditions, students described critical thinking as *Mechanical Thinking*, *Decision Making, Automatic Thinking* and *Criterial Thinking* (*Table 8:3 on p 224*). In general, there were two different sets of views about the importance of CTs in answering examination questions. Students from the UK and one from the international group (SS01_M_I_Bahrain) who had studied a British curriculum (see *Table 5:1 on p 74*) claimed that critical thinking skills were important in understanding and analysing exam questions. For example, (SS10_M_UK) said 'we take a lot of critical thinking to actually break down the questions and find out what it is you're trying to get'. (SS12_M_UK) claimed that all the exam papers involve some critical thinking: 'I would say all of them use some basic critical thinking, from just reading the question, and some require critical thinking in order to solve the problems'. (SS01_M_I_Bahrain) agreed: 'for MS I used lot of critical thinking … Definitely, critical thinking I believe is necessary to attempt the questions in every module'. Critical thinking is one of the most important components of academic skills in British education, therefore, students who have studied a British curriculum are aware of the likely importance of applying critical thinking skills in all situations, for example in *Analysing, Evaluating, Problem Solving* and *Decision Making*.

Contrarily, students from non-British educational backgrounds pointed out that, in exam conditions critical thinking is not required, though they believe CTs were useful when practising past exam papers as preparation for the exam. (SS07_M_EU_Poland) said 'it's like you use your practical knowledge … and then showing that skill in exam … we don't need much of critical thinking … it's just mechanical solutions … in exam you don't have to think deeply, you just solve it'. (SS06_M_EU_Greece) had a similar view: 'many questions require critical thinking especially in EE, the thing is that the way it's tested and assessed, it requires too much practice and mechanical thinking … during the practice you need the critical thinking, but in the exam you just have to write like a robot'. These two students found that critical thinking is important, but not required in writing answers to exam questions.

Although, students claimed that critical thinking is not required in answering exam questions, they related their thinking to *Mechanical Thinking*, or *Automatic Thinking*, and this seemed to have a direct connection to the DLC and PNE critical thinking model. In DLC, *Mechanical Thinking,* or *Automatic Thinking* requires the ability to think through a problem or question at various levels, for example from *Abstract* to *Concrete*, and in analysing statistical data, *Empirical* and *Scientific* thinking are required to solve a problem in an engineering context. On the other hand, in PNE, *Mechanical Thinking*, students need to apply *Intellectual Standards*, such as *Logic*, and in *Elements of Thinking* decide what *Concepts* are applicable to answer a particular exam question. Therefore, it is apparent that students were reporting applying their critical thinking skills in answering exam questions, although they called them *Mechanical Thinking,* or *Automatic Thinking*.

Students mentioned *Decision Making* and *Criterial Thinking* when explaining critical thinking in answering exam questions. *Decision Making*, was mentioned in relation to time saving and collecting marks. (SS02_M_Libya): 'It's about decision making in exam … You can't answer all the questions … I mean just get marks for the questions that you're sure about … During an exam I would skip these questions that require thinking'. (SS06_M_EU_Greece): 'During the exam you must not think, must see and decide immediately, otherwise you have to leave some questions'. Although these students believed that *Decision Making* should replace "thinking" in exam conditions, the blended thinking model of DLC, PNE and CDIO *(Table 8:3 on p 224*) shows that *Decision Making* does require critical thinking. In DLC, *Decision Making* involves the Analysis of a Complete Act of Thought (iii), (*see Table 3:1 on p 44*), especially in finding 'Suggestions and possible solutions using inferencing, supposition, guessing, or hypothesising'. Similarly, in PNE *Decision Making* requires application of *Intellectual Standards* such as *Accuracy* and *Relevance* to make a valid decision. In CDIO on the other hand, *Attitudes and Thought and Learning* (2.4.1), (see *Table 3:2 on p 49*), critical thinking is required in *Initiative and the Willingness to Make Decisions in the Face of Uncertainty*. Hence, based on the blended critical thinking model, it is clear that *Decision Making* requires general critical thinking skills (DLC), application of Intellectual Standards (PNE), and engineering critical thinking skills (CDIO) to make sound decisions. Deciding which exam question to answer may be a low decision, but to the extent that it is made rationality, it may draw to some extent on CTs.

Criterion Thinking was mentioned by one participant in relation to thinking in answering exam questions. (SS06_M_EU_Greece) 'criterial thinking … maybe in EE because it is not given directly … you have to compose a question and decide what is asked, what's the best way to follow in order to reach the required result'. Referring to the blended critical thinking framework, *Criterial Thinking* is made up of CTs and critical being and it appears in all three critical thinking models: DLC, PNE and CDIO. Criterial Thinking requires '… intelligence in discriminating and selecting of means and materials to resolve a practical or scientific problem', as suggested in DLC, *Thought: Abstract, Concrete, Empirical and Scientific Thinkin*g (ii), (see *Table 3:1 on p 44*). Within the *System Thinking* of CDIO (2.3) (see *Table 3:2 on p 49*) *Criterial Thinking* involves *Prioritization and Focus* (2.3.3). PNE provides the Intellectual Standards that engineering students can apply in *Criterial Thinking*, and this process helps in developing students' critical thinking skills.

Table 8:3 Students' Conception of Critical Thinking Skills Compared with Blended Conceptual Framework for Critical Thinking Skills for Foundation Year Engineering – Stage Two

Stage Two Interview	Blended Conceptual Framework for Critical Thinking for Engineering		
	DLC	PNE	CDIO
Mechanical Thinking	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (ii)	Intellectual Standards (Logicalness) Elements of Thinking (Concepts)	
Decision Making	The Analysis of a Complete Act of Thought (ACAT) – (iii)	Intellectual Standards (Accuracy and Relevance)	2.4 Attitudes, Thought and Learning (2.4.1)
Automatic Thinking	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (ii)		
Criterial Thinking	Thought: Abstract, Concrete, Empirical and Scientific Thinking (TACES) – (ii)	Intellectual Standards (Clarity, Accuracy, Relevance, Logicalness, Breadth, Precision, Significance, Depth)	2.3 System Thinking (2.3.3)

In sum, Stage Two interviews showed two different views on the importance of critical thinking views in answering exam questions. However, the analysis of students' responses against the blended critical thinking framework for foundation engineering shows that, students from British and non-British education were equally using CTs to some extent in answering examination questions.

iii. Students' Responses: Stage Three Interview

Students' understanding and attitude towards CTs were seen to have changed after a year of observations. *Table 8:4* (*on p 226*) below shows students' conception of critical thinking skills at Stage Three. Students' views on CTs, which were more divergent in their Stage One responses, have then converged to become more subject-specific to engineering, and in two exceptional cases became more philosophical. At Stage Three, the students defined critical thinking as *problem solving, independent thinking, sourcing, different points of view, learning how to learn and think*, and *picking up the truth*. Similar to their Stage One responses, a majority of the students at Stage Three conceptualised CTs as *problem solving*. For example, (SS02_M_Libya): 'you generate some other ways of solution just by trying to analyse the results and you come up with your own way of solving it'; (SS09_M_Cyprus): 'think about what you need to do to attack those certain problems then relevant solution and methods to tackle the tasks'. It was noted that, (SS09_M_Cyprus), still maintained his understanding of CTs as *identifying mistakes*, but also incorporated *problem solving:* 'see tricky things in a question, for example, you're given a question and how do you solve the questions'. It seemed that students at Stage Three were developing this strong focus on *problem solving* through their course work, laboratory work and mathematical skills in their engineering foundation course.

In contrast, two students adopted a philosophical approach in defining CTs. (SS13_M_USA): 'it means picking up the truth … not accepting what's given … you need to learn the truth', and (SS06_M_EU_Greece): 'my critical thinking is examining why something is true or not based on logic … I'm starting doubting everything in more in-depth'. At the time of the interview, when these views were expressed, it was noted that both these students were disappointed about their performance in their foundation year examination. (SS13_M_USA) was repeating some of the modules, while, (SS06_M_Greece) was repeating the whole FY programme. Their philosophical approach in defining critical thinking skills, and also their self-criticism could be due to lack of motivation, or confidence which affected their *Intellectual Courage* and *Intellectual Perseverance* as in the PNE (see *Figure 3:1 on p 46*).

Table 8:4 Students' Conception of CTs Compared with Blended Conceptual Framework for CTs for Foundation Year Engineering - Stage Three

Stage Three Interview	**Blended Conceptual Framework for Critical Thinking for Engineering**		
	DLC	PNE	CDIO
Problem solving	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (ii)	Elements of Thought	2.1 Analytical Reasoning and Problem Solving (2.1.1)
Independent thinking		Intellectual Traits (Intellectual Autonomy)	
Consider other point of view		Intellectual Traits (Intellectual Empathy)	3.1 Teamwork (3.1.1)
Sourcing			2.4 Attitudes, Thought and Learning (2.4.7)
Learning how to learn and think	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (i, ii, iii, iv)		2.3 System Thinking (2.3.1)
Picking up the truth			2.5 Ethics, Equity and Other Responsibilities (2.5.1)
Life skill	Thought: Abstract, Concrete, Empirical and Scientific - TACES (ii)		

These findings show that students' overall understanding of CTs gradually changed from general to more subject specific engineering thinking, most likely influenced by their learning experiences in the FY in learning and developing scientific engineering knowledge and skills. Stage Three shows students were more aligned with the CDIO engineering mode of thinking, and were also equally positioned between DLC and PNE on the general CTs skills and *intellectual traits*. This indicates that at this stage of their study, moving from their foundation year to their first year undergraduate programme, the students were still developing the general transferable and subject specific *intellectual skills*, and this trend held for all groups.

Students' attitude toward CTs remained the same at Stage Three, with the majority believing they were important: 'it's still important, it's not just purely apply in engineering, it's transferable skill', (SS07_M_Poland), 'my critical thinking of a foundation year has helped me, like adapt to the first year' (SS01_M_Bahrain); and 'I'm more aware I'm using critical thinking skills, and why I need to do that' (SS11_F_UK). At Stage Three, one student, (SS09_M_Cyprus) even mentioned the importance of CTs in answering exam questions: 'I think critical skills is important for engineering

… sometimes exam questions can be tricky'. This shows students had developed greater awareness about CTs having gone through the various teaching and learning activities of the FY, completed its assessments and coursework.

Though a majority of the students found that CTs were useful, two students expressed frustration: 'I for some reason, I feel that the further you progress in your years at uni the less critical you're able to be', (SS13_M_USA), and, 'I'm starting doubting everything … losing a point of reference in general', (SS06_M_Greece). These again are the two frustrated students who did not do well in the FY examination. Their failure in performing well in their FY exam was perceived as failure in a larger context and on personal grounds, and this again relates to *Intellectual Perseverance* (PNE, see *Figure 3:1 on p. 46*) and its effect on the students if they are lacking in this area.

8.3.2 Developing Students' Critical Thinking Skills: Practice and Pedagogy

Research Question 2: How do students learn and develop their critical thinking skills in the Engineering Foundation Year (EFY) programme?

a) To what extent do students have the opportunity to practise critical thinking skills in the engineering foundation year programme?
b) What types of critical thinking skills are students exposed to during the foundation year?
c) To what extent does students' prior learning influence their ability to learn and develop the skills in their foundation engineering study?

This question will be discussed from three perspectives, firstly from the students' viewpoints, followed by that of the module instructors, and finally by analysing the module profiles of the programme.

(i) Students' Responses

Most of the students responded that they had sufficient practice in CTs in the FY programme. Students mentioned repeatedly their opportunities to practise their critical thinking skills in both the Stage One and Stage Three interviews. They made reference to specific engineering subjects, for example, Mechanical Science (MS_X), Routes to Success (RTS_X), and Electronics and Electricity (EE_X) modules. Students related their practice in CTs mainly to workshops, support sessions, lab work, problem sheets, individual assignments, group work and project work.

Students had mixed views regarding CTs practice in the different FY semesters: 'first semester they introduce everything … second semester we directly started all things deeply', (SS07_M_Poland): 'semester one because we had more time to practise the skills', (SS11_F_UK): 'both semesters because they have different parameters', (SS06_M_Greece). Though students had mixed views, it was apparent that students recognised their general opportunities to practice CTs to solve basic engineering problems.

Students also found that some modules were better than others in providing opportunities to practise their CTs. In terms of students' choice, (RTS_X), (MS_X), (EE_X), and Maths (MTA_X) and (MTB_X), provided better opportunities to practise their skills: 'I think … Routes to Success module by definition is critical thinking', (SS06_M_Greece); 'MS and EE worksheets allow me to think around the question more', (SS11_F_UK); 'in terms of critical thinking … the language is maths and code', (SS10_M_UK). Of these three modules mentioned by students, when analysed based on documentary references to CTs, it was noted that (RTS_X), exposed students to *problem solving*, *reflection, critical evaluation* and *evaluate*, (MS_X), only to *problem solving*, and (EE_X), *problem solving* and *predictive skills*.

Students differed somewhat in their interpretations of CTs offered by individual modules, (SS06_M_Greece), interpreted the title of the module, 'Routes to Success', as referring to critical thinking in general terms. He seemed to be making a connection to the *Intellectual Traits* of engineering practice focusing on being successful if one is a critical thinker as in the PNE conceptual framework of CTs. (SS11_F_UK), however, related her experience in doing problem sheets, and thinking about solving a problem to practice in critical thinking. This focus on thinking about a problem is more a combination of DLC and CDIO. On the other hand, (SS10_M_UK), perceived that both the maths modules allowed him to interpret numbers and codes into mathematical language showing he was more focused on *Technical Skills* directly linked to engineering practice. This is evidence that students interpret the content of the modules they favour to learning and developing varied CTs in the FY programme.

The learning experiences of the students through course work, lab work, experiments, and group projects also meant they were constantly exposed to critical thinking in theory and practice. Students found the extra support incorporated within the FY programme was helpful in learning and developing CTs. (SS02_M_Libya), found labs were providing him with the opportunity to practice the skills, 'in labs … the experience itself, the lab experiment, but other things are mostly theoretical'. (SS01_M_Bharain) explained about the modelling of CTs in workshops: 'in class … brief understanding … worksheets came out of any topics … the workshops helped a lot … we saw how the professor solved it'. Students talked about lab work and working on their worksheets enabling them to practice CTs. Lab works needed them to apply their *investigative skills*, while the workshops and watching modelling of a problem solution developed their *analytical reasoning* and *problem solving skills* central to the CDIO critical thinking model. It seems students tended to learn and develop CTs both through experiments and through modelling from their tutors. This was also pointed out by (SS09_M_Greece): ‘my lecturer carry out a full experiment first … first practical experiment, discussion then theoretical information would be best for me’. It seems that, modelling could be one of the more effective ways to learn and develop CTs, even though not all module tutors were providing this.

Students are generally expected to practise the CTs in labs and workshops, and doing individual worksheets, and this may suggest that they are encouraged to engage in autonomous learning, taking responsibility for their own development in CTs. In addition, some but not all tutors are modelling CTs. However, this study offers no evidence that autonomous learning alone could promote critical thinking among students. Instead it seems likely that, the skills need modelling by the tutors as they are not best learnt in isolation, but through situated problem solving as thinking is tied to a particular context or subject.

(ii) Module Instructors’ Responses

Module instructors’ responses were more focussed on the pedagogical aspects of the FY programme. A majority of the module instructors responded that they do not teach critical thinking explicitly. However, they believed that students learn the skills from other teaching and learning activities, such as working on problem-sheets, asking questions, and attending workshops. (MI05_M_MS) explained that, ‘for each two hours of lecturing they have two hours problem class, where they have problem sheets … under the PGTAs’. This module instructor suggested that students were provided with extra support through postgraduate teaching assistants (PGTA) who guide them to complete the problem sheets. However, there was no evidence on whether PGTAs were actively modelling and guiding critical thinking engineering skills, or rather guiding students to complete a task mechanically. (MI04_F_EP), on the other hand, reported delivering her module through lectures: ‘lectures are delivering materials … give examples … introduce a new theory or principle’, followed by extra support from a related workshop.

Even though (M104_F_EP) ran her classes in lecture mode, there was evidence that students had opportunities to practice the CTs following her modelling, ‘giving examples’, where students could apply what they saw in solving other engineering problems. (MI01_F_MT) had a different approach to teaching, ‘I say Maths is not religion. I don’t like to give them formulas and say this is what you remember’. Again, this suggests that the tutors were providing opportunities to students to think for themselves, identify options and select the best to solve a problem. The pedagogical choices adopted by these three tutors reflect their philosophical approach to teaching. (MI05_M_MS_N) and (MIO4_F_EP_NN) were more focused on content and on task-based *problem solving* as in CDIO, whereas (MI01_F_MT_NN) was closer to the PNE model in building *Intellectual Traits*, i.e., *Intellectual Autonomy* and *Intellectual Perseverance* and to the CDIO on building *Attitudes, Thought and Learning*.

This analysis shows students were exposed to a range of technical and subject-specific CTs by their module instructors. However, the tutors were not explicitly drawing students' attention to CTs, even when they were providing opportunities for students to practise critical thinking skills, unlike, Ralston, (2013), where the tutors found that they were not explicitly teaching CTs, and therefore decided to incorporate CTs in their teaching by using the Paul and Elder critical thinking framework as a rubric for coursework assessment. This research shows that FY tutors may not undertake any explicit teaching of the skills, perhaps because the students are still at foundation level.

(iii) Module Profiles

Module profiles were analysed to find out to what extent the FY programme structure provided opportunities to students to learn and practise CT skills. Eighteen modules from two universities were analysed to answer this question and to identify the types of CTs included in the FY. Seventeen of the modules incorporated CTs in their learning outcomes, (see *Table 7:6 on p 212*). The types of CTs identified were *analyse, critical evaluation, evaluate, interpret, investigative skills, making judgement, predictive skills, problem solving* and *reflection*. It was also noted that, most modules had a combination of two or more types of CTs. The general specification document module (EFY_X) had the highest numbers of CTs mentioned. Then came the two language modules (PWA_X) and (PWB_X), followed by (CW_X) a project module at University X, and (RTS_X) a module which required students to write personal reflection on their progress as FY students. However, it was not clear in modules (PWA_X) and (PWB_X) how language is incorporated in the teaching and learning of CTs. Analysing the modules with the blended CTs conceptual framework, it was apparent that all the seventeen modules included references to technical CTs, including *programming*, *mathematical modelling*, *communications and teamwork* which are all closely linked to CDIO.

Prior Learning and Critical Thinking Skills

(i) Students' Responses

Student responses indicated that the majority of the overseas students were reasonably well prepared for UK higher education. The types of schooling or academic qualifications obtained prior to joining the FY programme had some influence on their confidence level and attitudes to critical thinking. Both European and International students were confident academically and were also able to use English Language confidently. One of the European students claimed his previous high school prepared him well for UK higher education: ‘I find myself quite confident, thanks to experience that I gained in my high school. My high school is good really good, it gave me this preparation for further education’, (SS09_M_Poland). Another overseas student from Bahrain talked about his previous schooling with a British curriculum, which could have influenced his high English Language proficiency and his preparedness for the engineering FY. (SS01_M_I_Bahrain): ‘in Bahrain I went to British school, and then when I shifted to Dubai I went to an international school and there I did the International Baccalaureate, a diploma programme, … it’s a private school … it had the British curriculum like they did A Levels’. It was clear from these responses that their prior learning experiences had a positive impact on these students’ learning and attitudes towards foundation year. This positive attitude resonates with the Paul, Niewoehner and Elder (PNE) critical thinking framework, which focuses on the person with the goal to develop essential *Intellectual Traits* in the thinker.

A majority of the students believed they had more opportunity to practise their critical thinking skills from their family than they had in school, except for one student (SS01_M_Bharain), who went to international school with British syllabus: ‘I always have been encouraged to be open minded, think critically, to think outside the box’. Several commented that they did not have opportunities to learn the CTs in schools, ‘like in my high school I don’t think you had any idea about critical thinking’, (SS02_M_Libya), and for (SS10_M_UK): ‘mine was more of sit down and listen … I didn’t enjoy learning’. In fact, almost nine from the ten students responded, that they had more opportunities to learn critical thinking skills from family than their school. (SS10_M_UK): ‘my Mum will influence me very much to think’; (SS13_F_UK): ‘I am a good critical thinker is just the way that I think I got from my dad’; (SS11_F_UK): ‘it’s like watching my dad … I inherited that streak!’. It was noted that these students had supportive families and were from privileged backgrounds. This motivation from the family to be a good thinker again aligns with PNE critical thinking framework in developing *Intellectual Traits* of the critical thinker.

(ii) Module Instructors’ Responses

Critical thinking skills were linked to the ability to use mathematical skills by some module instructors, therefore students who struggled with these skills were identified as lacking the logical and critical thinking skills. A tutor who taught mechanical engineering claimed that critical thinking could be challenging for returning to education, like the mature students.

(MI05_MS_M_N): '… just a purely logical thinking point of view is the biggest issue I would say. Mature students for some reasons … A lot of them seem to struggle with a+b = c'. Similarly another instructor who taught the computer course, (MI02_M_CPM_N) also found mature students lacked the ability to apply CTs, due to not having acquired mathematical skills: 'sometimes mature students struggle a little bit … because coming back to learning is difficult, and especially if they haven't studied Maths for a long time'. Hence, the mature students who did not have a good foundation in mathematical skills in their prior learning were perceived as students who lacked critical thinking skills. This view relates closely to the CDIO critical thinking framework which focuses on the micro skills of engineering practice. Engineering students are expected to have the ability to apply knowledge of mathematics, science and engineering principles to solve engineering problems, therefore any deficiency in this could be challenging for those mature students.

The research started with two hypotheses. Firstly, that FY students at the beginning of the course would have problems understanding and defining CTs due to insufficient content knowledge of scientific principles and engineering. Secondly, that international students would arrive without critical thinking knowledge and the ability to apply CTs. However, the findings dismissed these hypotheses, because it turned out that almost all participants had some prior knowledge of CTs, and they were able to conceptualise critical thinking in a general academic context at the beginning of the FY programme. As for the ability to apply critical thinking skills, the research found it was not the international students who had particular problems, but the mature students (according to some module instructors' who conceptualised critical thinking as mathematical skills).

8.3.3 Faculty's Perceptions and Goals for Students' Critical thinking and General Curricula for Engineering

Research Question 3: What is faculty's (lecturers') goal for students' critical thinking skills?

a) Are critical thinking skills evident in general curricula for the discipline of engineering foundation year module profiles and other documents? If yes, what types of skills are given preference?
b) How do the foundation year module instructors define critical thinking skills and how does this influence their pedagogical choices?

This question investigates the engineering FY course documents of two universities to find out if critical thinking is evident in all the modules offered in the programme and to what extent the FY aims align with general engineering curricula in preparation for an undergraduate engineering programme. In addition, the question explores how module instructors conceptualise critical thinking and how this influences their pedagogical choices.

(i) Types of Critical Thinking Skills Identified in EFY Module Profiles

A total of eighteen documents from the selected two universities were analysed, eleven modules from University X and seven from University Y, (see *Table 7:1 on p 182*). From the full set of documents, (EFY_X) was the main FY programme outline for engineering FY, and the (EES_X) was the main English Language programme outline. The remaining documents were individual module specifications for the subjects/courses offered in the programme. The types of CTs were identified in the documents and were grouped in nine main categories, which were: general engineering skills; learning outcomes; assessment; pedagogy; practice; academic English; aims; independent learning and knowledge. The analysis then examined two relationships: (i) critical thinking skills and categories, and (ii) critical thinking skills and individual modules.

The analysis of critical thinking and categories focused on the types of CTs evident within each category, and on the categories which have the highest number of CTs. The *skills* category was taken directly from the documents which referred to four main types of skills: *Intellectual Skills*, *General Transferable Skills*, *Practical Skills*, and *Subject-Specific Skills*. However, the four different types of skills were only explicitly stated in University X. Moreover, it was noted that all the four skills mentioned in the modules of University X were overlapping, it was not clear why they were listed as different skills in the *Learning Outcomes* (see *Table 8:4 on p. 226*). For example, *Analysis*, appears in, *Intellectual Skills*, *General Transferable Skills*, and *Technical Skills*. It was not clear if *Analysis* as a type of critical thinking skill has a different function, or interpretation within each category of the *skills.* However, this was not an issue with University Y, for it did not group the *skills* separately but placed them as *Skills* under the *Learning Outcomes* heading (category).

Table 8:5 Types of Critical Thinking Skills within the Four Engineering Skills in Learning Outcomes of University X and University Y

Types of Critical Thinking Skills Identified	Intellectual Skills	General Transferable Skills	Practical Skills-Subject Specific Skills	Technical Skills
Analysis	3	10	0	10
Critical Evaluation	0	1	0	0
Evaluation	0	10	0	11
Interpretive Skills	1	0	0	1
Investigative Skills	0	0	3	1
Making Judgments	0	0	0	1
Predictive Skills	1	0	3	0
Problem Solving	15	16	3	24
Reflection	0	1	0	0
TOTAL CTs	20	38	9	48

The findings shown in (*Table 8:4*) can be related to the research blended conceptual framework, which was made up of DLC, PNE and CDIO. Most of the critical thinking skills overlapped between the three frameworks, however, DLC does not include scientific *Predictive skills*. PNE on the other hand does not include *Interpretation* and *Reflection*, and the CDIO, *Critical Evaluation*, and *Reflection*. Although, each framework has missing skills and was not fully accommodating the types of skills which appeared in the document analysis, it was clear that all the types of critical thinking skills do appear in the blended framework as a whole. *Practical Subject-Specific* and *Technical Skills* seems to mostly appear in the CDIO framework, which is closely linked to engineering skills. *General Transferable Skills* appear more in the DLC. On the other hand, PNE partly accommodates *General Transferable* and, *Intellectual Skills*. *Table 8:4* also shows the relative importance of the nine types of CTs mentioned in the *Learning Outcomes* of both the universities. It is clear that *Problem Solving* skills are prioritised in the FY, followed by *Evaluation*, *Analysis*, *Interpretation*, *Investigative Skills*, and, *Making Judgements*. *Problem Solving* appeared mostly under *Technical Skills*, as one of the engineering skills.

Problem Solving skill is also applied in almost all the modules in the FY, for example, Engineering Principles (EP_X): 'Apply theoretical knowledge to solve simple practical problems in energy transport'; Maths (MT_Y): 'solve simple mathematical problems based on handling numbers and elementary algebraic techniques'. *Problem Solving* is one of the most essential skills engineering students must demonstrate in their studies and their future engineering practice, which could be the reason for this high number of appearances in all the documents. Engineering students are also required to demonstrate that they have the ability to conduct experiments and *Analyse* and *Evaluate* data is mentioned in AHEP, (2014) section 3.3 *(on p 42-43*). Therefore, these two skills have the second and third highest frequency in the course documents. However, the analysis shows that there is some obvious bias in the course documents regarding some important critical thinking skills such as, *Critical Evaluation* and *Reflection*, which are rarely mentioned in the module outlines. It is noted from the analysis that the FY programme gives preference to the engineering technical skills as end products of the course rather than developing students from the beginning as critical thinkers through *Critical Evaluation* and *Reflection*.

It is apparent that coursework (CW_X) and *writing reflective report*s (RTS_X) have incorporated the highest number of CTs. Besides these two modules, the two English Language modules at University X, (PWA_X) and (PWB_Y) have documented highest number of CTs with eighteen each. This however, seemed to be similar to the main course outline (EFY_X) of University X. A detailed analysis of the modules showed that the module descriptors of both the English modules were imitated from the main FY programme descriptors. This inclusion of CTs in module descriptors was not reflected in the findings from the interview data of English Language module instructors, who have expressed that both the language courses follow a prescribed syllabus, which was largely focused on grammar and academic writing skills.

(ii) Module Instructors' Conception of Critical Thinking and their Pedagogical Choices

Ten module instructors who represented almost all the modules taught in the FY programme took part in the interviews. However, University Y had only two instructors who took part and they were teaching Maths (MI09_MT_Y_N) and Electrical Engineering (MI10_EE_Y_N). From the total interviewed, eight tutors were from the Engineering faculty and the remaining two were from the English Language department.

Tutors were asked to define critical thinking based on their perception and understanding of the skills relevant to engineering and the definitions given by the tutors are shown in (*Table 8:5 on p 234)*. Tutors' definitions of critical thinking were noted to have close links to the CDIO framework for engineering critical thinking, with less emphasis on the critical thinking model for critical being PNE or on the philosophical understanding of CTs (DLC). The tendency of the tutors to frame their definitions of critical thinking as in CDIO also correlates with the analysis of FY course documents, where almost all the modules gave preference to *problem solving*, *evaluate*, and *analysis*. Tutors' definitions also resonate with changes in students' interview definitions of critical thinking, which narrowed over time to centre also on *problem solving*, as an essential skill in the CDIO framework.

Table 8:6 Module Instructors' Definition of Critical Thinking

CT definition	**Blended Conceptual Framework for Critical Thinking for FY Engineering**		
	Dewey's Logical Considerations (DLC)	Paul, Niewoehner and Elder (PNE)	CDIO
Identifying problem and solution	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (ii)		2.1 Analytical reasoning and Problem Solving (2.1.1)
Mathematical Thinking			2.2 Experimentation, Investigation and Knowledge Discovery
Self-critical	Analysis Complete Act of Thought (ACAT) – (i)	Intellectual Traits (Humility)	2.3 System Thinking (2.3.4)
Having Curious mind	Thought: Abstract, Concrete, Empirical and Scientific (TACES) - (i)		
Realise Limitations			2.4 Attitudes, Thought and Learning (2.4.1, 2.4.7)
Questioning the Authority		Intellectual Traits (Courage)	3.2 Communications (3.2.8)
Asking Question		The Elements of Thought (Questions)	3.2 Communications (3.2.8)
Creative and Critical Thinking	Thought: Abstract, Concrete, Empirical and Scientific Thinking (TACES) – (ii)	Intellectual Standards	
Weighing views		The Elements of Thoughts (Point of view)	3.1 Teamwork

The definition of critical thinking given by the tutors was cross checked against their pedagogical choices, as critical thinking instruction research claims that teachers' definition of critical thinking has a direct impact on their pedagogical choices. Tutors' interview findings described three main teaching modes in the FY, which were *lecture in combination with in-class practice, interactive*, and *traditional method*. Most of the tutors from the engineering faculty mentioned, *lecture in combination with in-class practice*. They explained that they use *lecture mode* to explain theories and concepts, and students were expected to have a good understanding of these. This was then, followed by in-class practice, which involved modelling *problem solving* in the same class. For more complex *problem solving,* students were expected to use the workshops and lab tasks, with support from workshop tutors and PGR teaching assistants. One of the engineering subject instructors (MI04_EP_F_NN) explained that lectures are for delivering subject content, not for teaching skills like CTs: 'lectures are … delivering materials, that's the main purpose of it. We don't do practice in the lectures, we have workshops to do practical'. As for her definition of critical thinking, she defined it as: '… have that curious mind to want to know … read a lot of books to understand the different systems'. This was reflected in her own mode of teaching which was, *lecture mode* and heavily content based.

Interactive method was another mode of teaching mentioned by a language tutor, (MI08_EES_F_N): '… very interactive to get them out, physically out of their seat as well, and get them to do things in groups'. This tutor defined critical thinking as '… weighing up other's views, or other things and not just weighing them up, but then going somewhere with it yourself … to some sort of conclusion'. This definition could be interpreted, that she conducts teaching and learning activities, which require discussion and decision-making. To compare her definition to the blended conceptual framework, her perception of critical thinking focused more on the development of a person or student as a critical thinker as reflected in *The Elements of Thought*, (PNE) which involved reasoning by listening to various points of view to come to a valid and desired conclusion.

Traditional method, was another teaching mode described by a language tutor, referring to a grammar focused language syllabus: '… the way the module is set up is basically, a massive focus on sentence structure … with grammar points' (MI06_PWB_F_N). Her definition of critical thinking had been 'to be able to think outside the box and being able to approach problem solving with a variety of either strategies or perspectives … to solve a problem'. This definition did not reflect her style of teaching, which was restricted by the prescribed syllabus, which did not encourage modelling of critical thinking in the class, nor provide opportunities for the students to practise the skills in the language classroom.

Overall however, the programme design and the teaching modes employed by the tutors in the programme could generally be related to each other, except for exceptional case of the language tutor (MI06_PWB_F_N).

8.3.4 Culture and Critical Thinking

Research Question 4: Does a student's cultural background affect his/her ability to learn and apply critical thinking skills?

This question will be analysed from two different perspectives, those of the students' and the module instructors'.

(i) Students' Responses

The research started with a hypothesis that a student's cultural background will affect his/her ability to apply critical thinking skills, based on discussion surrounding the issue in EAP literature. A broad definition of *culture* was adopted, including academic culture, which is related primarily to their immediate educational environment. Here students did notice some differences, for example (SS02_M_Libya), found that UK educational policy on retakes was different: '… the maximum you can retake in my country is three … you have to pass some modules, like you can't study Maths B or C without A, so you have to pass A'.

Another international student found the UK academic culture was less international than his previous educational experience. (SS01_I_Bahrain): 'the culture is very different from … living in Dubai which itself is an international hub'. The challenges of integrating with younger or less experienced classmates was expressed by mature student (SS13_M_USA): 'the biggest struggle of foundation year is the whole mature and immature culture clash, more than the lectures, and more than the material'. Contrary to the researcher's expectations, therefore, it seemed that variations in (educational) *culture* in this context did not influence students' learning and acquiring CTs, at least in their own perceptions. In fact, *culture* was not clearly mentioned in the critical thinking models used for this analysis. Only CDIO (see *Table 3:2 on p 49*), 3.2 *Communications,* (3.2.10) *Establishing Diverse Connections and Networking* could be perceived as establishing a shared cultural network among engineers potentially from diverse backgrounds and cultures.

Additionally, the analysis of the students' interview data did not identify any influence of the specific socio-cultural context of the students' origin on their development of CTs, as widely discussed in EAP practice. It needed to be acknowledged that *culture* has become highly complex in a globalised world and transcends traditional boundaries and nationalities. In Libya there are people who are highly religious, and follow strict religious tradition, where certain types of secular critical thinking are not acceptable. On the other hand, we have the example of student (SS02_M_I_Libya) who came from international education and was exposed to international *elite culture*, who was very ready for this kind of education. This clearly shows how students from the same country could have very different perspectives. The research project had a small, elite sample, where, families have invested in high quality education, and sent their children to elite international schools. It is clear that stereotypical labelling is no longer valid in such academic contexts. The findings on *culture* show that essentialist ideas of culture are increasingly out of date, in a globalising world.

There are clear implications from these findings for future English for Academic Purposes (EAP) research, especially the need to define *culture* before exploring the issue under investigation. EAP tutors should have a clear understanding of what critical thinking entails within the context of EAP, and to avoid stereotypical labelling of students' ability in critical thinking based on their nationalities or origins. The academic context requires open-mindedness in guiding students to develop the CTs required in the academic context; that is, the PNE critical thinking framework is also relevant for tutors, in achieving their goal of developing students as critical thinkers.

(ii) Module Instructors' Responses

Module instructors rarely mentioned *culture*, when mentioned *culture* was discussed with close links to CTs. In contrast to students' views, which were focused on *academic culture* the programme instructors did relate *culture* to students' nationalities. One EAP tutor, (MI06_PWA_F_N), made this kind of generalisation, for example: 'his ability to give … more mature complex responses to things was much better than the rest of my group, but there's also culture. Culture differences because, they're all different nationalities'. It was clear the tutor was stereotypically labelling students and their abilities to think critically with close reference to their nationalities or origins, keeping to traditional outdated views on international students. Our data suggest that, international students largely come from a good educational background, with supportive elite parents, and experience of travel. Therefore, it is no longer valid to categorise people and students, for example as, 'Arabs' subject to conservative Islamic thinking. Module instructors and tutors in the FY programme should have a good knowledge of contemporary issues surrounding EAP and engineering education; the CDIO critical thinking framework could be referred to as a reference to design more objective and neutral teaching and learning activities, and to approach teaching in a more flexible manner and with openness, celebrating diversity, observing inclusion, while opposing all forms of unfair discrimination based on origins and nationalities.

8.3.5 Academic English and Critical Thinking

Research Question 5: To what extent does language play a role for students in learning and applying critical thinking skills?

The question will be analysed from three perspectives: the students' view, the tutors' view, and any course document references to Academic English.

(i) Student Responses

The students who participated in the research had been judged proficient in the language, except for one student, (SS09_M_Cyprus) who was required to attend the (PWA_X) language support programme. Almost all students agreed that English Language plays a role in students' learning and applying CTs. For example, (SS06_M_Greece): 'critical thinking I think can make academic English much easier'; (SS10_M_UK): 'if you don't understand it, any of it, you can't really go on with critical thinking skills because you're stuck at that stage'; (SS09_M_Cyprus): 'engineering requires communication skills so, good level of English is a must'. Students' views were mainly focused on the communication aspect, which relates to both DLC and CDIO, concerning (3) Interpersonal Skills, Teamwork and Communication, (3.3) Communications in Foreign Languages, Communications in English (3.3.1).

Academic English as a mode of communication is an essential skill for engineering, especially in acquiring content knowledge, and working on multidisciplinary projects with members of diverse backgrounds with different first languages. However, engineering students do not need to be highly proficient in English before they can even begin to acquire CTs, partly because engineering students have the additional ability to solve engineering problems using mathematical or coding language.

(ii) Module Instructors' Responses

The analysis showed that almost all the instructors agreed there is an important relationship between *Academic English* and CTs, for example in *reflective writing* and *lab reports*. However, language was not perceived as a barrier which it could hinder students from thinking and studying in the engineering context. (MI03_M_WS_N) a senior tutor who was responsible for designing the Engineering Foundation Year programme at University X about twenty years ago, also explained that 'they've also got to master their communication skills with other people'. (MI06_EES_F_N) explained the importance of academic writing in general: 'most of them hadn't engaged in this certainly not in English … we did quite a lot of work on how to write the language and grammar'. This shows that in engineering practice *Academic English* is important in *writing reports* and *communication* as in CDIO (see *Table 3:2 on p 49*) (3) *Interpersonal Skills* to be functional in *teamwork*. Students understanding of the language and their ability to operate functionally in the engineering setting are closely linked to the CDIO thinking model, (3) *Interpersonal Skills: Teamwork and Communication,* (3.2) *Communications*, (3.2.3) *Written Communication*. The analysis on the whole did not show any very explicit understanding of how language plays a role in CTs, other than as a functional language in *Technical Skills*.

(iii) Module Profiles and Academic English

Analysis of module documents showed *Academic English* was an important component required in all the modules *in written exams, coursework, oral presentation* and *group work*. From eighteen modules analysed, the types of CTs identified for expression in writing were *analyse, evaluate, interpret* and *problem solving*. We have already seen that the language modules, (PWA_X) and (PWB_X) (see *Table 7:4 on p 197)*, had the highest frequency of CTs mentioned, similar to the main FY programme outline, (EFY_X). However, we have also shown that what was mentioned in the documents was not applied in the language classroom.

Academic English is useful to *interpret* and *evaluate* information, which is vital in *problem solving*, for any misinterpretation could lead to technical disaster in an engineering context. With reference to the research conceptual framework, the importance of language and communications in engineering is closely linked to CDIO as it is important for *interpersonal skills* as in *team work* and *communications*, especially in (3.2.3) *Written Communication*, (3.2.6) *Oral Communication* and, (3.2.7) *Inquiry, Listening and Dialog*. In sum, to function effectively as FY students, a high level of academic competence is essential, and the English Language benchmark set by the university is effective; the non-native students who participated in the research and who were above this threshold were generally succeeding in the programme. Therefore, once that threshold is accomplished, students can progress successfully and draw on other skills like mathematics and scientific thinking skills to identify and solve engineering problems.

Chapter 9 Conclusion and Recommendations

9.1 Introduction

The main aim of this research was to investigate Engineering Foundation Year (EFY) students' understanding and attitudes towards critical thinking, and how they learn and develop critical thinking skills (CTs) in the EFY programme at UK universities. A second aim was to investigate the relationship between teaching and learning practice within the EFY programme and how this contributes to the development of CTs among students. The aims were achieved firstly, by conducting semi-structured interviews with EFY students and module instructors, and secondly, by conducting document analysis on EFY programme modules. To analyse the data, a blended conceptual framework for critical thinking for engineering FY based on DLC (1910), PNE (2006) and CDIO (2011) was designed to identify the types of CTs students and module instructors were engaged in during foundation year, and how far these skills were evident in the modules offered in EFY.

9.2 Original Contributions of the Thesis: Empirical Findings

The first research question concerned students' perceptions and attitudes towards critical thinking at the beginning and at end of the FY programme. Students' responses at three different stages of their study showed that their understanding of CTs began as general thinking skills (DLC), which were more divergent in Stage One, and then converged to become more subject specific to engineering (CDIO) in Stage Three, with a majority conceptualising CTs as *Problem Solving*. Students' attitude towards CTs at the beginning of the FY were mixed. While they held a sense of their importance, they also had uncertainties about them varying from confidence to frustration. At the final interviews, a majority of the students maintained that CTs were important in their FY and claimed that the skills helped them to adapt to their first year of their undergraduate programme successfully. The students' positive changes in their perceptions and attitudes towards CTs indicated that they were gradually developing these skills, and the direction of development was consistent with their learning experiences in the FY.

The pedagogic plans and practices of the FY concerning CTs were analysed based on three different data sources: students' viewpoints, that of module instructors, and finally through analysis of the FY programme module profiles. Most students claimed that, they had practice in CTs in the FY programme through coursework, laboratory work, experiments, and group projects, but did not refer to any explicit discussion of critical thinking by their module instructors in class.

This was confirmed by the analysis of module instructors' responses, who reported, they were not explicitly teaching CTs to the students in their foundation level classes. However, the document analysis of the FY modules explicitly referred to nine different types of CTs; *analysis, critical evaluation, evaluate, interpret, investigative skills, predictive skills* and *problem solving* to which students should be exposed in the FY. It seemed that tutors also believed that these skills would mainly be learned through coursework, laboratory works and projects. However, it was clear that some tutors did also model certain CT skills within their main classes, for example when working through problems. Overall, it seems that FY students were sufficiently exposed to certain CTs through varied activities embedded in the FY programme, to develop their CTs in the FY in the general direction expected by the programme and by instructors.

It was also apparent that students' previous learning and culture did not greatly influence their ability to learn and apply CTs in their foundation engineering study. This finding contradicts the expectation of some existing literature that claimed most overseas students would find it quite challenging to learn and develop CTs as critical thinking or criticality were not part of their prior learning culture. The majority of the overseas students in this study were well prepared for UK higher education, though their ability to use CTs was largely influenced by their supportive family and privileged background. Hence, the findings are not applicable to all overseas students with more diverse backgrounds.

The research also hypothesised that language would play a key role in students learning CTs, based on the existing literature in academic English and critical thinking. However, the finding indicates that students who had achieved the university entry threshold in English Language were able to learn and apply CTs effectively. In engineering practice, academic English can also be complemented with mathematical or coding language to identify and reformulate problems and to achieve desired outcomes in the various *technical skills, intellectual skills, practical subject-specific skills* and *transferable skills* to which students were exposed to in FY.

The findings also illuminate the types of CTs students were exposed to in the engineering FY programme which were, *problem solving* mainly and followed by *analyse, evaluate, critical evaluation, interpret, investigative skills, making clear judgement, predictive skills* and *reflection*. These same skills were also the focus of assessment through *coursework assignments, written assessment, oral presentation*, and *group project*. The findings clearly indicate the specific CTs practised in engineering FY.

Overall, the research has achieved its aims in investigating the development of CTs in engineering FY by exploring the theory and practice at UK universities through its methodology, which has helped in producing meaningful findings, which have answered the research questions with empirical evidence. The literature review on critical thinking theory and thinking models in general and engineering in particular has led to the development of a research conceptual framework, which is the *Blended Conceptual Framework for Critical Thinking for Engineering Foundation Year*. This framework has contributed greatly in data analysis to identifying the general and specific CTs for engineering and the intellectual traits expected from engineering students, as well as those which are actually developed in practice during the FY.

9.3 Original Contributions of the Thesis: Blended Conceptual Framework for Critical Thinking for Engineering Foundation Year

The second original contribution of the thesis is the *Blended Conceptual Framework for Critical Thinking for Engineering Foundation Year*. The blended framework draws upon *Dewey's Logical Considerations* (DLC), *The Engineering Reasoning Model of Paul, Niewoehner and Elder* (PNE) and *Conceive Design Implement Operate* (CDIO) Critical Thinking Model. It can also be related to the Accreditation of Higher Education Programmes for Engineering Council, UK (2014). There was a need to design a blended framework for engineering FY for this research because, at the start of the research, it was quite challenging to find a broad framework to understand the types of CTs and the intellectual traits which students possess on entry, and also those required from engineering students, particularly for FY.

The selected critical thinking models used to design the blended framework derived from both philosophical and engineering perspectives. It includes the general CTs (DLC). FY students are expected to bring from their previous learning, the Intellectual Traits (PNE) students are expected to develop gradually, and engineering specific CTs (CDIO), which is the objective of engineering education to produce engineers as professionals and critical thinkers resolving engineering problems. The framework proved extremely useful in interpreting both educational priorities of the engineering FY concerning CTs, and also the intellectual journeys of the students in the study, from their home context through the FY experience and onward to an undergraduate engineering programme.

Having been validated qualitatively in this way, the framework could be used by others in the future to understand the academic needs of EFY students in developing their CT skills, and to design teaching and assessment materials to suit best the FY engineering programme, taking into account the likely starting point of FY students. Therefore, programme developers in this programme should consider it in course or module design to accommodate to the academic needs of the FY students as preparation for their destination undergraduate engineering course.

9.4 Limitations of the Study and Recommendations for Future Research

Although the research illuminates some useful findings for future research, it has some limitations concerning: firstly, student participants, secondly, module instructors, thirdly, methodology, and finally, research setting.

Firstly, the research could have produced clearer information on the role of academic English and its effect on CTs, if a substantial number of students from the language support programme had participated in the research. However, in practice, students who volunteered for this research mostly had met the university's English Language requirement and were confident users of the language. Therefore, the research findings that claim that academic English does not heavily influence students' learning and development of the CTs is not applicable to all overseas students.

It also proved quite challenging to recruit FY students from University Y as case studies for this project, and the students who participated in the research were only from University X. Students' interview data from University Y would have been very useful, because a large proportion of their FY students were mature students, unlike University X, which largely recruited students who had just completed their secondary school. The study found a distinct difference between tutors from University X and University Y's perceptions towards mature students. From the tutor interviews it was obvious, that tutors from University Y had more positive perceptions compared to University X, in terms of mature students' success and CTs. In particular, University Y tutors found mature students were intrinsically motivated for professional development, unlike younger students who found aspects of the FY programme boring and repetitive of the A Levels. As we have seen, it was the mature students at University X who expressed the most negative feelings about the FY programme. However, without students' case study data from University of Y, it is not possible to pursue how far maturity is influential in the acquisition of CTs, whether positively or negatively.

Secondly, it was also quite challenging to find volunteers among module instructors from the language support programme. However, the module instructors from the Engineering faculty were very supportive. Hence, the findings, concerning module instructors' viewpoints were mainly from engineering faculty, and we could not access sufficient information to understand fully the instructional practice on CTs in the language classroom.

Besides that, the questions posed to the module instructors focused on their general perceptions towards critical thinking and engineering, pedagogical choices, students' critical development and to what extent the FY programme contributes to development in their CTs. It would be worthwhile to have a question on tutor's educational philosophy and ethics in engineering education, since none of the tutors interviewed mentioned ethics as one of the essential skills for engineering students. Thirdly, there were inevitable limitations arising from the qualitative research methodology used in the study. The research initially conducted a mixed method approach using online questionnaires to be triangulated with students' interviews and to observe the overall development of FY students at both University X and University Y, alongside the conduct of longitudinal student case studies. This approach would have provided stronger generalisability than the all-qualitative approach which was eventually adopted. However, the sample who participated in the survey and answered the CTs questionnaire was not sufficient, therefore the data was not included in the data analysis presented in this thesis. The numbers of participants would have increased if both online and paper versions of the questionnaire were given.

To develop further such a mixed methods approach, it would be especially useful to develop a test of CT skills specific to engineering, which could be used to assess the development of the students CTs at the beginning and at the end of the FY Programme. However, this could be challenging to design for a researcher from humanities, so collaboration between humanities and engineering expertise would be necessary to provide an achievable outcome that is to design a critical thinking test for engineering involving the module instructors of engineering FY.

Finally, the setting of the research is based in the UK and the findings could be used to understand issues surrounding CTs for engineering in the UK. However, engineering education is a global profession beyond culture and language, therefore, it would be a useful further step to conduct a comparative study with students from other countries enrolled in similar FY programme. This would further test current claims that students from different locations will have distinctive differences in their perception towards CTs based on their previous learning, first language and culture. It would establish how far module instructors from different locations have different viewpoints on CTs for engineering education and the necessary CTs. Again, the conceptual framework developed in this study could provide a coherent theoretical underpinning for this kind of comparative research.

In a sum, future study investigating students' development in critical thinking should include students of diverse background, different FY programmes, different settings outside the UK and a mixed method approach for comprehensible findings which could be generalised for programme designing, testing and evaluation, materials designing and teacher training.

List of References

Abd. Rashid, M. Chew, J. and Kabilan, M.K. (2006) Meta cognitive Reading Strategies of Good Malaysian Chinese Learners. *Malaysian Journal of ELT Research*, Vol.2, pp.21-41.

Abrami, P.C., Bernard, R.M., Borokhovski, E, Wade, A., Surkes, M.A., Tamim, R. and Zhang, D. (2008) Instructional Interventions Affecting Critical Thinking Skills and Dispositions: A Stage 1 Meta-Analysis. *Review of Educational Research*, Vol. 78(4), pp. 1102-1134.

Accreditation Board of Engineering and Technology. (2010) *Criteria for Accrediting Engineering Programs: Effective for Evaluation during the 2010-2012 Accreditation Cycle, 2010*. Available at: https://www.abet.org/

Accreditation of Higher Education Programmes. (2014) *UK Standard for Professional Engineering Competence* (3rd edition.). Engineering Council. Available at: https://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/

Adair, D. and Jaeger, M. (2015) Cultivation of critical thinking in undergraduate engineering education. *43rd Annual SEFI Conference June* 29 – July 2, 2015 Orleans, France.

Adair, D. and Jaeger, M. (2016) Incorporating Critical Thinking into an Engineering Undergraduate Learning Environment. *International Journal of Higher Education*, Vol. 5(2), pp. 23-39.

Ahern, A., O'Connor, T., McRuair, G., McNamara, M., and O'Donnell, D. (2012) Critical Thinking in the university curriculum – the impact on engineering education. *European Journal of Engineering Education*, Vol. 37(2), pp. 125-132.

Aida Suraya Md. Yunus, H, R., Ahmad Tarmizi, R., Abu, R., Md. Nor, S., Ismail, H., Wan Ali, W.Z. and Abu Bakar, K. (2005) Problem Solving Abilities of Malaysian University Students. *International Journal of Teaching and Learning in Higher Education*, Vol. 17(2), pp. 86-96.

Alagozlu, N. and Suzer, S.S. (2010) Language and Cognition: Is Critical Thinking a Myth in Turkish Educational System? *Procedia – Social and Behavioural Sciences*, Vol. 2, pp. 782-786.

Alexander, O., Argent, S. and Spencer, J. (2008) *EAP Essentials: A teacher's guide to principles and practice*. Reading: Garnet Publishing, pp. 251-270.

Aliakbari, M. and Sadeghdaghighi, A. (2012) Teachers' perception of the barriers to critical thinking. Akdeniz Language Studies Conference 2012. *Procedia – Social and Behavioral Sciences*, Vol. 70, pp. 1-5.

Alnofaie, H. (2013) A framework for implementing critical thinking as a language pedagogy in EFL preparatory programmes. *Thinking Skills and Creativity,* 10, pp. 154-158.

Alvesson, M. and Deetz, S. (2000) *Doing Critical Management Research*. Thousand Oaks, CA.: Sage.

Amin, Astuti Muh and Adiansyah, Romi, (2018) Lecturers' Perceptions on Students' Critical Thinking Skills Development and Problems Faced by Students in Developing their Critical Thinking Skills. *Indonesian Journal of Biology Education*, Vol. 4(1), pp. 1-10.

Andreas POHL. (2005) Language Learning Histories: An Introduction to Critical Thinking. *Paper presented at the 18th Annual EA Education Conference*, English Language Centre.

Arum, R. and Roksa, J. (2011) *Academically Adrift: Limited Learning in College Campuses*. Chicago: University of Chicago Press.

Association of American Colleges and Universities (2011). *The LEAP vision for learning: Outcomes, practices, impact, and employers' view*. Retrieved from the Association of American Colleges Universities. Available at:
http://www.aacu.org/sites/default/files/files/LEAP/leap_vision_summary.pdf

Atkinson, D. (1997) *A critical approach to critical thinking*. Milton Keyness: SRHE and Open University Press.

Axelrod, P. (2002) *Values in Conflict: the University, the Marketplace, and the Trials of Liberal Education*. Quebec: McGill-Queen's University Press.

Bailin, S. and Siegel, H. (2003) Critical Thinking. In Blake, N., Smeyers, P., Smith, R., and Standish, P. (ed.) *The Blackwell Guide to the Philosophy of Education*. Oxford: Blackwell Publishing.

Bailin, S., Case, R., Coombs, J.R. and Daniels, L.B. (1999) Conceptualizing critical thinking. *Journal of Curriculum Studies*, Vol. 31(3).

Baker, T.L. (1994) *Doing Social Research* (2nd edn.), New York: McGraw-Hill Inc.

Barnawi, O.Z. (2011) Finding a Place for Critical Thinking and Self-voice in College English as a Foreign Language Writing Classrooms. *English Language Teaching*, Vol. 4(2), pp. 190-197.

Barnett, R. (1997) *Higher education: A critical business.* Buckingham: Society for Research into Higher Education and Open University Press.

Barrie, S. (2006) Understanding what we mean by the generic attributes of graduates. *Higher Education*, Vol. 51 (2), pp. 215-224. Barnett, R. (1997) *Higher education: A critical business*. Milton Keynes: SRHE and Open University Press.

Behar-Horenstein, L.S. and Niu, L. (2011) Teaching Critical Thinking Skills in Higher Education: A Review of the Literature. *Journal of College teaching & Learning,* Vol. 8(2), pp. 25-42.

Benesch, S. (2001) *Critical English for academic purposes*. Mahwah, NJ: Erlbaum.

Beyer, B.K. (1995) *Critical Thinking*. Indiana: Phi Delta Kappa Educational Foundation Bloomington.

Blaikie, N. (2010) *Designing Social Research: The Logic of Anticipation*. Cambridge, M.A.: Polity Press.

Bogdan, R.C., Biklen, S.K. (2007) Data analysis and interpretation. *In Qualitative research for education: An introduction to theories and method.* Toronto: Pearson. pp. 159-197.

Braun, N.M. (2004) Critical Thinking in the Business Curriculum. *Journal of Education for Business*, Vol. 79(4), pp. 232- 236.

Brookfield, S.D. (1987) *Developing Critical Thinkers: Challenging Adults to Explore Alternative Ways of Thinking and Acting*. England: Open University Press.

Brookfield, S.D. (2003) Critical Thinking in Adulthood. In Fasko, D. (ed), *Critical Thinking and Reasoning: Current Research Theory and Practice*. Cresskill, NJ: Hampton.

Brown, K. (1998) *Education, Culture and Critical Thinking*. Ashgate Aldershot.

Browne, M.N. and Freeman, K. (2000) Distinguishing Features of Critical Thinking Classroom. *Teaching in Higher Education*, Vol. 5(3).

Brumfit, C., Myles, F., Mitchell, R., Johnston, B. and Ford, P. (2005) *Language study in higher education and the development of criticality*. International Journal of Applied Linguistics, Vol. 15(2), pp. 145 -168.

Bryman, A. (2012) *Social Research Methods*. (4th ed.), New York: Oxford University Press.

Canadian Engineering Accreditation Board (CEAB) (2010) *Accreditation Criteria and Procedures*. Available at http://www.engineerscanada.ca/e/pu_ab.cfm.

Cavanagh, S. (1997) Content analysis: concepts, methods and applications. Nurse Researcher, 4(3), pp. 5-16.

Conceive Design Implement Operate. (2011) The CDIO Syllabus v2.0: An Updated Statement of Goals for Engineering Education. Available at: http://www.cdio.org/knowledge-library/documents/cdio-syllabus-v20-updated-statement-goals-engineering-education-0.

Chamot, A. (1995) Creating a community of thinkers in the ESL/EFL classroom. *TESOL Matters*, Vol. 5 (5).

Chan, H.M. and Yan, H.K.T. (2007) Is there a Geography of Thought for East-West Differences? Why or why not? *Educational Philosophy and Theory,* pp. 383-403.

Chan, N.M. Ho, I.T. and Ku, K.Y.L. (2011) Epistemic beliefs and critical thinking of Chinese students. *Learning and Individual Differences, 21, pp. 67 – 77.*

Chang, Pei-Fen and Wang, Dau-Chung. (2011) Cultivating engineering ethics and critical thinking: a systematic and cross-cultural education approach using problem-based learning. *European Journal of Engineering Education,* Vol. 36(4), pp. 377-390.

Chapple, L. and Curtis, A. (2000) Content-based instruction in Hong Kong: Student responses to film. *System,* Vol. 28(3), pp. 419-433.

Cheah, Sim-Moh. (2011) Developing Critical Thinking Skills through Dynamic Simulation Using an Explicit Model of Thinking. *7th International CDIO Conference 2011*, June 20-23, Technical University of Denmark, Copenhagen.

Cheng, A. (2006) Analyzing and enacting academic criticism: The case of an L2 graduate learner of academic writing. *Journal of Second Language Writing*, Vol.15, pp. 276-306.

Claris, L. and Riley, D. (2012) Situation critical: critical theory and critical thinking in engineering education. *Engineering Studies*, Vol. 4(2), pp. 101-120. Available at: http://dx.doi.org/10.1080/19378629.2011.649920

Clarke, L.E. and Gabert, T.F. (2004) Faculty issues related to adult degree programs. *New Directions for Adult and Continuing Education*, Vol. (10), pp. 31-40.

Crawley, E.F., Lucas, W.A., Malmqvist, J. and Brodeur, D.R. (2011) The CDIO Syllabus v2.0: An Updated Statement of Goals for Engineering Education. *Proceedings of the 7th International CDIO Conference*, Technical University of Denmark, Copenhagen, June 20-23, 2011.

Cuypers, S.E. (2004) Critical thinking, autonomy and practical reason. *The Journal of Philosophy of Education*, Vol. 38(1), pp. 75-90.

de Jager, T. (2012) Can first year students' critical thinking skills develop in a space of three months? *Procedia Behavioural Sciences* Vol. (47), pp. 1373-1381.

Delors, Jacques. (1996) *Report to UNESCO on Education for the 21st Century-Learning: A treasure within*. Paris: UNESCO.

Denzin, N.K. and Lincoln, Y.S. (2008) Introduction: The Discipline and Practice of Qualitative Research. In N.K. Denzin and Y.S. Lincoln (Eds.). *The Landscape of Qualitative Research*. Thousands Oak, California: Sage Publications. pp. 1-45.

Dewey, J. (1910) *How We Think*. Boston; New York: D.C. Heath & Co., Publishers.

Dewey, J. (1933) How We Think: A Restatement of the Relation of Reflective Thinking in the Educative Process Vol. (8). Southern Illinois Up.

Dewey, J. (1938) *Experience and education*. New York: Collier Books, Macmillan.

Dong, Y.R. (2006) Learning to think in English. *Educational Leadership*, Vol. 64(2), pp.22-26.

Dornyei, Z. (2007) *Research Methods in Applied Linguistics: Quantitative, Qualitative and Mixed Methodologies*. Oxford: OUP.

Douglas, E. (2009) The Practice of Critical Thinking Among Engineering Students. *American Society for Engineering Education.*

Douglas, E. P. (2012) Defining and measuring critical thinking in engineering. *Procedia – Social and Behavioral Sciences*, Vol. (56), pp. 153-159.

Doyle, J.K. (2004) "Introduction to interviewing techniques". In Wood, D.W. (Eds.), *Handbook for IQP Advisors and Students*. Worcester Polytechnic Institute, Worcester, MA.

Drever, E. (1995) *Using Semi-structured Interviews in Small-scale Research: A Teacher's guide*. Glasgow: The Scottish Council for Research Education.

Durkin, K. (2008) The middle way: East Asian Master's students' perceptions of critical argumentation in UK universities. *Journal of Studies in International Education,* Vol. 12(1), pp. 38-55.

Dwyer, C.P., Boswell, A. and Elliott, M.A. (2015) An Evaluation of Critical Thinking Competencies in Business Settings. *Journal of Education for Business,* pp. 1-10.

Dwyer, C.P., Hogan, M.J. and Stewart, I. (2012) An evaluation of argument mapping as a method of enhancing critical thinking performance in e-learning environments. *Metacognition Learning,* Vol. 7, pp. 219-244.

Dym, C.L., Agogino, A.M., Eris, O. Frey, D.D. and Leifer, L.J. (2005) Engineering Design Thinking, Teaching and Learning. *Journal of Engineering Education*, pp. 103-120.

Edstrom, K. and Kolmos, A. (2014) PBL and CDIO: Complementary models for engineering education development. *European Journal of Engineering Education*, Vol. 39(5), pp. 539-555.

Edward, F.C., Malmqvist, J. Ostlund, S., Brodeur, D.R. and Edstrom, K. (2014) The CDIO Syllabus: Learning Outcomes for Engineering Education. In Edward, F.C., Malmqvist, J. Ostlund, S., Brodeur, D.R. and Edstrom, K., (2014) *Rethinking Engineering Education*, 2nd ed. Switzerland: Springer International Publishing. Chapter: 3.

Egege, S and Kutieleh, S. (2004a) Critical Thinking and International Students: A Marriage of Necessity *Dealing with Diversity* First Year in Higher Education Conference, Monash University, July 2004. Available at: www.fyhe.qut.edu.au/past_papers/papers04.htm.

Egege, S. and Kutieleh, S. (2004b) Critical thinking: Teaching foreign notions to foreign students. *International Education Journal*, Vol. 4(4), pp.75-85.

Eckensberger, L.H. (2003) Wanted: a contextualized psychology. A plea for cultural psychology based on actual psychology. In T.S. Saraswathi, (Eds.). *Cross-cultural perspectives in human development: Theory, research and applications*. New Delhi: Sage Publications. pp. 70-101.

Elder, L. (2005) Critical Thinking as the Key to the Learning College: A Professional Development Model. *New Directions for Community Colleges,* No. 130, pp. 39-48.

Ellwood, C. and Nakane, I. (2009) Privileging of Speech in EAP and Mainstream University Classrooms: A Critical Evaluation of Participation. *TESOL Quarterly*, Vol. 43(2), pp.203-230.

Emir, S. (2009) Education faculty students' critical thinking disposition according to academic achievement. *Procedia Social and Behavioral Sciences,* Vol. (1), pp. 2466 – 2469.

Ennis, R.H. (1962) A concept of critical thinking. *Harvard Educational Review*, 32/1, pp. 81-111.

Ennis, R.H. (1987) A taxonomy of critical thinking abilities and dispositions. In Baron, J. and Sternberg, R. (Eds.) *Teaching Thinking Skills*. New York: W.H. Freeman. pp. 9-26.

Ennis, R.H. (1989) Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher*, Vol. (18), pp. 4-10.

Ennis, R.H. (1996) Critical Thinking Dispositions: Their Nature and Assessability. *Informal Logic,* Vol. 18(2 & 3), pp. 165-182.

European Network for Accreditation of Engineering Education. (2008) *EUR-ACE Framework Standards for Accreditation of Engineering Programmes*, 2008. Available at: https://www.enaee.eu/doc/eur-ace-framework-standards-for-first-and-second-cycle-degrees-i-freeston/

Evers, E.W. (2007) Culture, Cognitive Pluralism and Rationality. *Educational Philosophy and Theory*, pp. 364-382.

Facione, P.A. (1990) *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction*. Millibrae, CA: The California Academic Press.

Facione, P.A. (2000) The Disposition Toward Critical Thinking: Its Character, Measurement, and Relationships to Critical Thinking Skill. *Informal Logic,* Vol. 20(1), pp. 61-84.

Facione, P.A. and Facione, N.C. and Giancarlo, C.A.F. (1997) *Professional Judgement and the Disposition toward Critical Thinking*. CA: The California Academic Press.

Felder, R.M. and Brent, R. (2004) The Intellectual Development of Science and Engineering Students. Part 2: Teaching to Promote Growth. *Journal of Engineering Education*, October 2004, pp.279-291.

Fisher, A. (2001) *Critical Thinking: An Introduction*. Cambridge: CUP.

Fisher, A. and Scriven, M. (1997) *Critical Thinking: its definition and assessment.* Norwich, UK: Centre for Research in Critical Thinking.

Fleming, J, Garcia, N. and Morning, C. (1995) The Critical Thinking Skills of Minority Engineering Students: An Exploratory Study. *Journal of Negro Education*, Vol. 64(4), pp 437-453.

Flick, U. (2009) *An Introduction to Qualitative Research* (4^{th} edn). Thousands Oaks, C.A.: Sage Publications.

Fontana, A. and Frey, J.H. (1998) "Interviewing, the art of science". In Denzin, N.K. and Lincoln, Y.S. (Eds.). *Collecting and Interpreting Qualitative Materials*. Sage, Thousand.

Foundation Courses in the UK, (2017). Available at: http://www.studyin-uk.com/study-options/foundation. (Access on 03/02/2017).

Freire, P. (1970) *Pedagogy of the oppressed*. New York: Seabury.

Fuchs, M. (2004) At one Catholic College, crucifixes make a comeback. *New York Times*, 12th June.

Gellin, A. (2003) The Effect of Undergraduate Student Involvement on Critical Thinking: A Meta-Analysis of the Literature 1991-2000. *Journal of College Student Development,* pp. 746-762.

Gibbins, L., Perkin, G. and Sander, G. (2016) Developing the Critical Thinking Skills of Students in Civil and Building Engineering at Loughborough University. *Proceedings of INTED2016 Conference*, *7th - 9th March 2016*, Valencia, Spain, pp. 8299-8309.

Glaser, E. M. (1941) *An experiment in the development of critical thinking.* New York: Columbia University Teachers College.

Godfrey, E. and Parker, L. (2010) Mapping the Cultural Landscape in Engineering Education. *Journal of Engineering Education*, pp. 5-22.

Goh, C.T. (1997) Shaping our future: Thinking Schools, Learning Nation. *Singapore Government Press Release*. Speech by Prime Minister Goh Chok Tong at the Opening of the 7th International Conference on Thinking, June 1-6, Singapore.

Gunnink, B. and Bernhardt, K,L. (2002) Writing, Critical Thinking and Engineering Curricula. *32nd ASEE/IEEE Frontiers in Education Conference*, November 6-9, 2002.

Halpern, D.F. (1997) *Critical thinking across the curriculum: A brief edition of thought and knowledge*. Mahwah, NJ: Lawrence Erlbaum Associates.

Halpern, D.F. (1999) Teaching for Critical Thinking: Helping College Students Develop the Skills and Dispositions of a Critical Thinker. *New Directions for Teaching and Learning,* No. 80, pp. 69-74.

Halstead, J.M. (2004) 'An Islamic concept of education'. *Comparative Education*, Vol. 40(4), pp. 517-529.

Halx, M.D. and Reybold, L.E. (2005) A Pedagogy of Force: Faculty Perspectives of Critical Thinking Capacity in Undergraduate Students. *The Journal of General Education,* Vol. 54 (4), pp. 293-315.

Hammersley-Fletcher, L. and Hanley, C. (2016) The use of critical thinking in higher education in relation to the international student: Shifting policy and practice. *British Educational Research Journal*, Vol. 42(6), pp. 978-992.

Hannabuss, S. (1996) "Research interviews". *New Library World*, Vol. 97 No. 1129, pp. 22-30.

Hart Research Associates (2013). *It Takes More Than A Major: Employer Priorities for College Learning and Student Success.* Retrieved from The American Association of Colleges and Universities website. Available at: https://www.aacu.org/sites/default/files/files/LEAP/2013_EmployerSurvey.pdf

Heijltjes, A. Van Gog, T. Leppink, J. and Paas, F. (2014) Improving critical thinking: Effects of dispositions and instructions on economics students' reasoning skills. *Learning and Instruction 29*, pp 31-42.

Hove, S.E. and Anda, B. (2005) Experiences from Conducting Semi-structured Interviews in Empirical Software Engineering Research. *11th IEEE International Software Metrics Symposium (METRICS)*, IEEE Computer Society.

Howard, L.W., Tang, T.L.P. and Austin, M.J. (2015) Teaching Critical Thinking Skills: Ability, Motivation, Intervention, and the Pygmalion Effect. *Journal of Business Ethics*, Vol. 128, pp. 133-147.

Hsieh, Hsiu-Fang and Shanon, S.E. (2005) Three Approaches to Qualitative Content Analysis. *Qualitative Health Research*, Vol. 15(9), pp. 1277-1288. Available at: http://www.qaa.ac.uk/publications/information-and-guidance/publication/?PubID=2910#.Wcoczsh96M_

Huntzinger, D.N. (2007) Enabling Sustainable Thinking in Undergraduate Engineering Education. *International Journal of Engineering Education,* Vol. 23(2), pp. 218-230.

Hyland, K. and Hamp-Lyons, L. (2002) EAP: issues and directions. Journal of English for Academic Purposes, Vol. 1, pp. 1-12. Retrieved from: https://www.journals.elsevier.com/journal-of-english-for-academic-purposes

Imenda, S. (2014) Is There a Conceptual Difference between Theoretical and Conceptual Framework? *Journal of Social Science*, Vol. 38(2), pp. 185-195.

Irvine, A. Drew, P. and Sainsbury, R. (2012) 'Am I not answering your questions properly?' Clarifications, adequacy and responsiveness in semi-structured telephone and face-to-face interviews. *Qualitative Research*, Vol. 13(1), pp. 87-106.

Jen, C.H. and Lien, Y.W. (2010) What is the source of cultural influences? Examining the influence of thinking style on the attribution process. *Acta Psychologica,* Vol. 133, pp. 154 – 162.

Jenkins, E.K. (2010) The Significance Role of Critical Thinking in Predicting Auditing Students' Performance. *Journal of Educational for Business*, pp. 274-279.

Jessop, J.L.P. (2002) Expanding Our Students' Brainpower: Idea Generation and Critical Thinking Skills. *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*.

Jin, Yu-Fang, (2018) Training Students for Critical Thinking in an Electrical Engineering Core Course*. Proceedings of the 2018 ASEE Gulf-Southwest Section Annual Conference*, The University of Texas and Austin, April 4-6, 2018.

Johnson, R.H. (1992) The problem of defining critical thinking. In S.P. Norris (Ed.), *The generalizability of critical thinking: Multiple perspectives on an educational ideal*. New York, NY: Teacher College Press. pp. 38-53

Johnston, B., Mitchell, R., Myles, F. and Ford, P. (2011). *Developing student criticality in higher education: Undergraduate learning in the arts and social sciences.* London: Bloomsbury.

Jonassen, D., Strobel, J., and Lee, C.B. (2006) Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education,* 95(2), pp. 139-151.

Kek, M.Y.C.A. and Huijser, H. (2011) The power of problem-based learning in developing critical thinking skills: preparing students for tomorrow's digital futures in today's classrooms. *Higher Education Research & Development*, Vol. 30(3), pp. 329-341.

Kirby, J.R., Woodhouse, R.A. and Ma, Y. (1996) Studying in second language: The experience of Chinese students in Canada. In D.A. Watkins and Biggs, J.B. (Eds.), *The Chinese Learner: Cultural, Psychological and Contextual Influences.* Hong Kong and Melbourne: CERC & ACER. pp. 141-158.

Kirn, A. and Benson, L. (2018) Engineering Students' Perceptions of Problem Solving and Their Future. *Journal of Engineering Education*, Vol. 107(1).

Koda, K. (2007) Reading and Language Learning: Cross linguistic Constraints on Second Language Reading Development. *Language Learning*, Vol. 57(1), pp. 1-44.

Kroes, P. (2015) Critical thinking and liberal studies in engineering. *Engineering Studies*, Vol. 7(2-3), pp. 126-128.

Kubota, R. (1999) Japanese Culture Constructed by Discourses: Implications for Applied Linguistics Research and ELT. *TESOL Quarterly*, Vol. 33(1), pp. 9-31.

Kurfiss, J.G. (1988) *Critical Thinking: Theory, Research, Practice, and Possibilities. ASHE-ERIC Higher Education Report No. 2, 1988*. ASHE-ERIC Higher Education Report: The George Washington, DC.

Kvale, S. and Brinkmann, S. (2009) Inter Views: Learning the Craft of Qualitative Research Interviewing, Los Angeles, CA.: Sage.

Kwak, Duck-Joo. (2007) Re-conceptualizing Critical Thinking for Moral Education in Culturally Plural Societies. *Educational Philosophy and Theory*, pp. 460-470.

Landsman, J. and Gorski, P. (2007) Countering standardization. *Educational Leadership*, Vol. 64 (8), pp. 40-41.

Lewis, J., Hieb, J. and Whetley, D. (2010) Introduction to Critical Thinking to Freshman Engineering Students. *American Society for Engineering Education.*

Li, J.F. and Liu, G.Z. (2006) On the training of critical thinking. *Journal of Northwest Normal University (Social Sciences),* Vol. 43 (3), pp. 63-67.

Liaw, Meei-Ling, (2007) Content-Based Reading and Writing for Critical Thinking Skills in an EFL Context. *English Teaching and Learning*, Vol. 31(2), pp. 45-87.

Lingard, L., Albert, M. and Levinson, W. (2008) Grounded theory, mixed methods and action research. *BMJ*, Vol. 337, pp.459-461.

Lipman, M. (1988) Critical Thinking: What can it be? *Analytic Teaching*, Vol. 8, pp. 5-12.

Lipman, M. (2003) *Thinking in Education (2nd edn.)*. Cambridge: CUP.

Liu, D. (2005) Plagiarism in ESOL students: Is cultural conditioning truly the major culprit? *ELT Journal*, Vol. 59, pp. 234-241.

Lun, V.M.C., Fischer, R. and Ward, C. (2010) Exploring cultural differences in critical thinking: Is it about my thinking style or the language I speak? *Learning and Individual Differences,* Vol. 20, pp. 604 -616.

Lunt, B.M. and Helps, C.R.G. (2001) Problem Solving in Engineering Technology: Creativity, estimation and critical thinking are essential skills. *Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition*, American Society for Engineering Education.

Mackey, A. and Gass, S.M. (2005) *Second Language Research: Methodology and design*. New Jersey: Routledge.

Mangena, A. (2003) Strategies to overcome obstacles in the facilitation of critical thinking in nursing education. *Unpublished Dissertation*, Rand Afrikaans University.

Manola, E. Kusumi, T., Koyasu, M., Michita, Y. and Tanaka, Y. (2013) To what extent do culture-related factors influence university students' critical thinking use? *Thinking Skills and Creativity,* Vol. 10, pp. 121-132.

Marjoram, T. (2010) History of engineering: engineering at UNESCO. In *Engineering: Issues, Challenges and Opportunities for Development*. UNESCO Report.

Martin, J. R. (1992). Critical thinking for a humane world. In S. P. Norris (Ed.), *Thegeneralizability of critical thinking: Multiple perspectives on an educational idea. New York: Teachers College Press.* pp. 163–180.

Masek, A. and Yamin, S. (2012) The Impact of Instructional Methods on Critical Thinking: A Comparison of Problem-Based Learning and Conventional Approach in Engineering Education. *International Scholarly Research Network,* ISRN Education, Vol. 2012, Article ID 759241.

Mason, M. (2007) Critical Thinking and Learning. *Educational Philosophy and Theory*. pp. 339-349.

Maudsley, G. and Strivens, J. (2000) Promoting professional knowledge, experiential learning and critical thinking for medical students. *Medical Education*, Vol. 34(7), pp. 535-544.

McBride, R.E., Xiang P. and Wittenburg, D. (2002) Dispositions toward critical thinking: The preservice teachers' perspective. Teachers and Teaching: *Theory and Practice*, Vol.8, pp. 29-40.

McPeck, J.E. (1981) *Critical thinking and education*. Oxford: Martin Robertson.

McPeck, J.E. (1990) *Teaching critical thinking. Dialogue and dialectic*. London: Routledge.

McPeck, J.E. (2016) *Critical Thinking and Education*. London; Ontario: Routledge Library Editions.

Melles, G. (2003) *Critical Thinking in ESL for postgraduate engineers: negotiating a discipline. English for Specific Purposes*, Vol. 2(5).

Melles, G. (2008) Teaching critical appraisal skills to postgraduate, English as a second language, engineering students. *Australasian Journal of Engineering Education*, Vol. 14 (2), pp. 23-32.

Michaluk, L.M., Martens, J., Damron, R.L. and High, K.A. (2016) Developing a Methodology for Teaching and Evaluating Critical Thinking Skills in First-Year Engineering Students. *International Journal of Engineering Education* Vol. 32, No.1(A), pp. 84-99.

Miekley, J.P. (2014) What Makes Critical Thinking Critical for Adult ESL Students. *The CATESOL Journal*, Vol. 25(1), pp. 143-150.

Miettinen, R. (2000) The concept of experiential learning and John Dewey's theory of reflective thought and action. *International Journal of Lifelong Education*, Vol. 19(1), pp. 54-72.

Mina, M. Omidvar, I. and Knott, K. (2003) Learning to Think Critically to Solve Engineering Problem: Revisiting John Dewey's Ideas for Evaluating Engineering Education. *Paper presented at the 110th ASEE Annual Conference*, Nashville, TN.

Minakova, L.Y. (2014) Critical Thinking Development in Foreign Language Teaching for Non-language-majoring Students. *Procedia – Social and Behavioural Sciences 154*, pp. 324 – 328.

Mok, J. (2010) The New Role of English Language Teachers: Developing Students' Critical Thinking in Hong Kong Secondary School Classrooms. *The Asian EFL Journal Quarterly*, Vol. 12(2), pp. 262-287.

Moore, T. (2004) The critical thinking debate: how general are general thinking skills? *HERD*, Vol. 23, pp. 3-18.

Moore, T.J. (2011) Critical Thinking and Language: *The Challenge of Generic and Disciplinary Discourse*. London; New York: Continuum International Publishing Group.

Moore, T. (2013) Critical Thinking: Seven Definitions in Search of a Concept. *Studies in Higher Education*, Vol. 38(4), pp. 506-522.

Niewoehner, R.J. (2006) Applying a critical thinking model for engineering education. *World Transactions on Engineering and Technology Education*, Vol. 5(2), pp. 341-344.

Niewoehner, R.J. and Steidle, C.E. (2009) The Loss of the Space Shuttle Columbia: Portaging Leadership Lessons with a Critical Thinking Model. *Engineering Management Journal*, Vo. 21(1), pp. 9-18.

Nisbett, R. (2003) *The Geography of Thought: How Asians and Westerners Think Differently … and Why?* New York, NY: The Free Press.

Nussbaum, M.C. (1997) *Cultivating Humanity: A Classical Defence of Reform in Liberal Education*. Cambridge; Massachusetts; London: Harvard University Press.

Opdenakker, R. (2006) Advantages and disadvantages of four interview techniques in qualitative research. *Forum: Qualitative Sozialforschung / Forum: Qualitative Social Research*, Vol. 7 (4), pp.1-9.

Ozyurt, O. (2015) Examining the Critical Thinking Dispositions and the Problem Solving Skills of Computer Engineering Students. *Eurasia Journal of Mathematics, Science & Technology Education*, Vol. 11(2), pp. 353-361.

Pally, M. (2001) Skills Development in 'Sustained' Content-Based Curricula: Case Studies in Analytical/Critical Thinking and Academic Writing. *Language and Education*, Vol. 15(4), pp. 279-305.

Papadopoulos, C., Rahman, A. and Bostwick, J. (2006) Assessing Critical Thinking in Mechanics in Engineering Education. *American Society of Education*.

Pariser, B. (2001) Teaching Critical Thinking. *Proceedings of the 2001 American Society for Engineering Education Annual Conference and Exposition,* American Society for Engineering Education, TCI, The College for Technology.

Pascarella, P. (1997) The secret of turning thinking into action. *Management Review*, Vol. 86(3), pp. 38-39.

Pascarella, E.T and Terenzi, P.T. (1991) *How college affects students: Findings and insights from twenty years of research.* San Francisco, CA: Jossey-Bass.

Pasch, A. (1959) Dewey and the Analytical Philosophers. *The Journal of Philosophy*, Vol. 56(21), pp. 814-826.

Patchamuthu, S. (2010). *Critical Thinking and academic-based reading in English: a question analysis in English for Academic Purposes course books for ESL/EFL students*. Unpublished MA Dissertation, University of Essex, United Kingdom.

Paton, M. (2005) Is critical analysis foreign to Chinese students? In. E. Manalo and Wong-Toi, G. (Eds.), *Communication Skills in University Education: The international dimension.* Auckland: Pearson Education. pp. 1-11.

Patton, M.Q. (2001) *Qualitative Research and Evaluation Methods*. Thousand Oaks, C.A.: Sage Publications.

Paul, R. (1982) Teaching critical thinking in the strong sense: a focus on self-deception, worldviews and dialectical mode of analysis. *Informal Logic Newsletter*, Vol. 4(2), pp. 2-7.

Paul, R. (1989) Critical Thinking in North America: A new theory of Knowledge learning literary. *Argumentation*, Vol. 3, pp. 197-235.

Paul, R. (2005) The State of Critical Thinking Today*. New Directions for Community Colleges*, No.130, pp. 27-38.

Paul, R. and Elder, L. (1994) Critical Thinking: Using Intellectual Standards to Assess Student Reasoning. *Journal of Development Education*, Boone, N.C. Vol. 18(2).

Paul, R. and Elder, L. (2002) Critical Thinking: *Tools for taking charge of your professional and personal life*. Upper Saddle, NJ: Prentice-Hall.

Paul, R. and Elder, L. (2003) *A Miniature Guide to Scientific Thinking*. Sonoma: Foundation for Critical Thinking.

Paul, R. and Elder, L. (2009) *Critical thinking: Concepts and tools*. Dillion Beach, CA: The Foundation for Critical Thinking.

Paul, R. and Elder, L. (2014a) *Critical Thinking: Tools for Making Charge of Your Professional and Personal Life* (2nd edn). New Jersey: Pearson Education, Inc.

Paul, R. and Elder, L. (2014b) *The Miniature Guide to Critical Thinking Concepts and Tools*. Foundation for Critical Thinking.

Paul, R. Elder, L., and Bartell, T. (1996) Research findings and policy recommendations study of 38 public and 28 private universities to determine faculty emphasis on critical thinking instruction. Available at: http://www.criticalthinkng.org/pages/study-of-38-public-universities-and 28-private-universities-to-determine-faculty-emphasis-on-critical-thinking-in-instruction/598

Paul, R. and Elder, L. (2014b) *The Miniature Guide to Critical Thinking Concepts and Tools*. Foundation for Critical Thinking.

Paul, R., Elder, L. and Bartell, T. (1997) California teacher preparation for instruction in critical thinking: Research findings and policy recommendations. *Foundations for Critical Thinking*, Santa Rosa: CA.

Paul, R., Niewoehner, R. and Elder, L. (2006) *The Thinker's Guide to Engineering Reasoning*. Foundation for Critical Thinking: Tamales, CA.

Paul, R. (1985) Critical Thinking Research: A Response to Stephen Norris. *Educational Leadership*, Vol. 42(8), pp. 519-526.

Pawley, A. L. (2009) Universalized narratives: Patterns in how faculty members define "engineering". *Journal of Engineering Education,* Vol. 98(4), pp. 309-319.

Phelan, A. (2001) The Death of a Child and the Birth of Practical Wisdom. *Studies in Philosophy and Education,* Vol. 20, pp. 41-55.

Phillips, V. and Bond, C. (2004) Undergraduates' experiences of critical thinking. *Higher Education research & Development*, Vol. 23(3), pp. 277-294.

Pithers, R.T. and Soden, R. (2000) Critical Thinking in Education: A Review. *Educational Research*, Vol. 42, pp. 237-249.

Podsakoff, P.M., MacKenzie, S.B. and Podsakoff, N.P. (2003) Common method biases in behavioural research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, Vol. 88, pp. 879-903.

Pritchard, J.W. and Mina, M. (2012) Hands-on, discovery, critical thinking, and freshman engineering: A systems level approach to learning and discovery. *American Society for Engineering Education Annual Conference*, ASEE.

Ralston, P.A. (2013) Enhancing Critical Thinking Across The Undergraduate Experience: An Exemplar From Engineering. *American Journal of Engineering*, Fall 2013, Vol. 4(2), pp. 119-126.

Ralston, P.A. and Bays, C.L. (2015) Critical Thinking Development In Undergraduate Engineering Students From Freshman Through Senior Year: A 3-Cohort Longitudinal Study. *American Journal of Engineering Education*, Vol. 6(2), pp. 85-98.

Rapley, J.T. (2001) The art (fullness) of open-ended interviewing: some considerations and analysing interviews. *Qualitative Research*, Vol. 1(3), pp 303-323.

Rapley, J.T. (2007) *Doing conversation, discourse and document analysis*. London: Sage.

Richards, K. (2003*) Qualitative Inquiry in TESOL*. Basingstoke: Palgrave.

Richmond, J.E.D. (2007) Bringing critical thinking to the education of developing country professionals. *International Education Journal*, Vol. 8(1), pp. 1-29.

Rickles, M.L., Schneider, R.Z., Slusser, S.R., Williams, D.M. and Zipp, J.F. (2013) Assessing Change in Student Critical Thinking for Introduction to Sociology Classes. *Teaching Sociology*, Vol. 41(3), pp. 271-281.

Riley, N.S. (2004) A Struggle over Mind and Soul. *New York Times*, September 8th.

Rodgers, C. (2002) Defining Reflection: Another Look at John Dewey and Reflective Thinking. *Teachers College Record*, Vol. 104(4), pp. 842-866.

Rogers, T. and Kalmanovitch, T. (2005) Recording Transcribing. University of Calgary. Psychology: USA. Available at: http://apmc.newmdsx.com/CATA/resources/B1-Recording%20and%20Transcribing.pdf.

Rubin, H.J. and Rubin, I.S. (2005) *Qualitative Interviewing: The Art of Hearing Data* (2nd edn.). Thousand Oaks, CA: Sage.

Rudd, R., Baker, M. and Hoover, T. (2000) Undergraduate Agriculture Student Learning Styles and Critical Thinking Abilities: Is there a relationship? *Journal of Agriculture Education,* Vol. 41(3), pp. 2-12.

Saito, N. and Imai, Y. (2004) In the search of the public and private: philosophy of education in post-war Japan. *Comparative Education*, Vol. 40 (4), pp. 583-594.

Sale, D. and Cheah, Sin-Moh. (2011) Developing Critical Thinking Skills through Dynamic Simulation Using an Explicit Model of Thinking. *7th International CDIO Conference* 2011, June 20-23, Technical University of Denmark, Copenhagen.

Salmi, J. (2001) Tertiary Education in the 21st Century: Challenges and Opportunities. *Journal of the programme on Institutional management in Higher Education,* Vol. 13(2), pp. 105-130.

Salsali, M., Tajvidi, M. and Ghiyasvandian, S. (2013) Critical Thinking Dispositions of Nursing Students in Asian and Non-Asian Countries: A Literature Review. *Global Journal of Health Science*, Vol. 5 (6), pp. 172-178.

Scriven, M., and Paul, R. (2007). *Defining critical thinking.* The Critical Thinking Community: Foundation for Critical Thinking. Available at*:* *http://www.criticalthinking.org/aboutCT/define_critical_thinking.cfm*

Sert, N. (2006) EFL student teacher's learning autonomy. Asian EFL Journal, 8(2). Available at: http://www.asian-efl-journal.com/

Shaheen, N. (2016) International students' critical thinking-related problem areas: UK university teachers' perspectives. *Journal of Research in International Education*, Vol. 15(1), pp. 18-31.

Shenghong, J. and Dan, J.W. (2004) The contemporary development of the philosophy of education in mainland China and Taiwan. *Comparative Education*, Vol. 40 (4), pp. 571-581.

Shenton, A.K. (2004) Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, Vol. 22, pp. 63-75.

Shirkani, S. and Fahim, M. (2011) Enhancing Critical Thinking in Foreign Language Learners. *Procedia – Social and Behavioral Sciences*, Vol. 29, pp. 111-115.

Siegel, H. (1988) *Educating Reason: Rationality, Critical Thinking and Education*. New York: Routledge.

Siegel, H. (1990) McPeck, informal logic, and the nature of critical thinking. In McPeck, J.E. (Eds.) *Teaching critical thinking*. London: Routledge, pp. 75-85.

Siegel, H. (1992). The generalizability of critical thinking skills, dispositions, and epistemology. In S.P. Norris (Ed.), *The generalizability of critical thinking: Multiple perspectives on an educational ideal*. New York, NY: Teachers College Press. pp. 97-108.

Siegel, H. (1999) Argument Quality and Cultural Difference. *OSSA Conference Archive,* Paper 50*.*

Siegel, H. (2002) Multiculturalism, Universalism, and Science Education. In Search of Common Ground. *Wiley Periodicals, Inc*. pp. 803-820.

Siller, T.J. (2001) Sustainability and Critical Thinking in Civil Engineering Curriculum. *Journal of Professional Issues in Engineering Education and Practice*, Vol. 127, pp. 104-108.

Smith, G.F. (2003) Beyond critical thinking and decision thinking and decision-making: Teaching business students how to think. *Journal of Management Education*, Vol.27 (1), pp. 24-51.

Smith, G.F. (2002) Thinking Skills: The question of generality. *Journal of Curriculum Studies*, Vol. 34(6).

Stapleton, P. (2001) Assessing critical thinking in the writing of Japanese university students: Insights about assumptions and content familiarity. *Written Communication*, Vol. 18, pp. 506-548.

Strauss, A. (1995) Notes on the Nature of Development of General Theories. *Qualitative Inquiry*, Vol. 1(1), pp. 7-18.

Subject Benchmark Statement (Engineering). (2015) UK Quality Code for Higher Education: Part A: Setting and maintaining academic standards. Available at: https://www.qaa.ac.uk/docs/qaa/subject-benchmark-statements/sbs-engineering-15.pdf?sfvrsn=f99df781_10

Swales J.M. and Feak, C.B. (1994) *Academic writing for graduate students: Essential tasks and skills*. Ann Arbor: The University of Michigan Press.

Takano, Y. and Noda, A. (1993) A Temporary Decline of Thinking Ability during Foreign Language Processing. *Journal of Cross-Cultural Psychology*, Vol. 24(4), pp. 445-462.

Talmy, S. (2010) Qualitative Interviews in Applied Linguistics: From Research Instrument to Social Practice. *Annual Review of Applied Linguistics*, (30), pp. 128-148.

Tan, C. (2017) Teaching critical thinking: Cultural challenges and strategies in Singapore. *British Educational Research Journal*, Vol. 43 (5), pp. 988-1002.

Thomson, C. (2009). *Critical Reasoning: a practical introduction*. London: Routledge.

Tiwari, A., Lai, P., So, M., and Yuen, K. (2006) A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. *Medical Education*, Vol. 10(6), pp. 547-554.

Tsui, L. (2001) Faculty Attitudes and the Development of Students' Critical Thinking. *The Journal of General Education,* Vol. 50(1).

Tsui, L. (2002) Fostering Critical Thinking through Effective Pedagogy: Evidence from Four Institutional Case Studies. *The Journal of Higher Education*, Vol. 73(6), pp. 740-763.

United Nations Educational Scientific and Cultural Organisations, (2010) Engineering: Issues, Challenges and Opportunities for Development. *UNESCO Report*. France: UNESCO.

University Foundation Courses, (2017) Available at: *http://www.click-courses.com/content/campaigns/university_foundation_courses.aspx*

Welch, K.C., Hieb, J. and Graham, J. (2015) A Systematic Approach to Teaching Critical Thinking Skills to Electrical and Computer Engineering Undergraduates. *American Journal of Engineering Education,* Vol. 6(2), pp. 113-123.

Wiles, R., Charles, V. and Crow, G. (2006) Researching researchers: lessons for research ethics. *Qualitative Research*, Vol. 6(3), pp. 283-299.

Woodward-Kron, R. (2002) Critical analysis versus description? Examining the relationship in successful student writing. *Journal of English for Academic Purposes*, Vol. 1(2), pp. 121-143.

Yim, Ip., Lee, W., D.T.F., Lee, I.F.K., Chau, J.P.C., Wootton, Y.S.Y. and Chang, A.M. (2000) Disposition towards critical thinking: a study of Chinese undergraduate nursing students. *Journal of Advanced Nursing*, Vol. 32(1), pp. 84-90.

Zhu, W. (2004) Writing in business courses: an analysis of assignment types, their characteristics, and required skills. *English for Specific Purposes*, Vol. 23, pp. 111-135.

Appendix A **CDIO Syllabus v1.0**

Table 1. CDIO Syllabus v1.0 at the Second Level of Detail

1 TECHNICAL KNOWLEDGE AND REASONING 1.1 KNOWLEDGE OF UNDERLYING SCIENCE 1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE 1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE **2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES** 2.1 ENGINEERING REASONING AND PROBLEM SOLVING 2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY 2.3 SYSTEM THINKING 2.4 PERSONAL SKILLS AND ATTITUDES 2.5 PROFESSIONAL SKILLS AND ATTITUDES	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION** 3.1 MULTI-DISCIPLINARY TEAMWORK 3.2 COMMUNICATIONS 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES **4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT** 4.1 EXTERNAL AND SOCIETAL CONTEXT 4.2 ENTERPRISE AND BUSINESS CONTEXT 4.3 CONCEIVING AND ENGINEERING SYSTEMS 4.4 DESIGNING 4.5 IMPLEMENTING 4.6 OPERATING

Table 2. CDIO Syllabus v2.0 at the Second Level of Detail
(Underlined Text is Updated from v1.0)

1 DISCIPLINARY KNOWLEDGE AND REASONING 1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCE 1.2 CORE FUNDAMENTAL KNOWLEDGE OF ENGINEERING 1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS **2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES** 2.1 ANALYTICAL REASONING AND PROBLEM SOLVING 2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY 2.3 SYSTEM THINKING 2.4 ATTITUDES, THOUGH AND LEARNING 2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION** 3.1 TEAMWORK 3.2 COMMUNICATIONS 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES **4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT** 4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT 4.2 ENTERPRISE AND BUSINESS CONTEXT 4.3 CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT 4.4 DESIGNING 4.5 IMPLEMENTING 4.6 OPERATING

Appendix B **Condensed CDIO Syllabus v2.0**

CONDENSED CDIO SYLLABUS v2.0
JUNE 2011

1 DISCIPLINARY KNOWLEDGE AND REASONING
- **1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES**
- **1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE**
- **1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS**

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- **2.1 ANALYTICAL REASONING AND PROBLEM SOLVING**
  - 2.1.1 Problem Identification and Formulation
  - 2.1.2 Modeling
  - 2.1.3 Estimation and Qualitative Analysis
  - 2.1.4 Analysis With Uncertainty
  - 2.1.5 Solution and Recommendation
- **2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY**
  - 2.2.1 Hypothesis Formulation
  - 2.2.2 Survey of Print and Electronic Literature
  - 2.2.3 Experimental Inquiry
  - 2.2.4 Hypothesis Test and Defense
- **2.3 SYSTEM THINKING**
  - 2.3.1 Thinking Holistically
  - 2.3.2 Emergence and Interactions in Systems
  - 2.3.3 Prioritization and Focus
  - 2.3.4 Trade-offs, Judgment and Balance in Resolution
- **2.4 ATTITUDES, THOUGHT AND LEARNING**
  - 2.4.1 Initiative and the Willingness to Make Decisions in the Face of Uncertainty
  - 2.4.2 Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility
  - 2.4.3 Creative Thinking
  - 2.4.4 Critical Thinking
  - 2.4.5 Self-awareness, Metacognition and Knowledge Integration
  - 2.4.6 Lifelong Learning and Educating
  - 2.4.7 Time and Resource Management
- **2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES**
  - 2.5.1 Ethics, Integrity and Social Responsibility
  - 2.5.2 Professional Behavior
  - 2.5.3 Proactive Vision and Intention in Life
  - 2.5.4 Staying Current on the World of Engineering
  - 2.5.5 Equity and Diversity
  - 2.5.6 Trust and Loyalty

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- **3.1 TEAMWORK**
  - 3.1.1 Forming Effective Teams
  - 3.1.2 Team Operation
  - 3.1.3 Team Growth and Evolution
  - 3.1.4 Team Leadership
  - 3.1.5 Technical and Multidisciplinary Teaming
- **3.2 COMMUNICATIONS**
  - 3.2.1 Communications Strategy
  - 3.2.2 Communications Structure
  - 3.2.3 Written Communication
  - 3.2.4 Electronic/Multimedia Communication
  - 3.2.5 Graphical Communication
  - 3.2.6 Oral Presentation
  - 3.2.7 Inquiry, Listening and Dialog
  - 3.2.8 Negotiation, Compromise and Conflict Resolution
  - 3.2.9 Advocacy
  - 3.2.10 Establishing Diverse Connections and Networking
- **3.3 COMMUNICATIONS IN FOREIGN LANGUAGES**
  - 3.3.1 Communications in English
  - 3.3.2 Communications in Languages of Regional Nations
  - 3.3.3 Communications in Other Languages

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS
- **4.1 EXTERNAL, SOCIETAL, AND ENVIRONMENTAL CONTEXT**
  - 4.1.1 Roles and Responsibility of Engineers
  - 4.1.2 The Impact of Engineering on Society and the Environment

Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Copenhagen, June 20 – 23, 2011

Appendix C **email copy to Director of EFY**

Mail - Patchamuthu S. - Outlook - Internet Explorer

https://outlook.office.com/mail/deeplink?version=2019090201.07&popoutv2=1

Reply all | Delete | Spam | Block | ···

RE: Arrange for an appointment

From: Patchamuthu S.
Sent: 15 November 2014 20:01
To: [redacted]
Cc: [redacted].
Subject: Arrange for an appointment

Dear [redacted]

Hope all is well.

1. I am going to start my pilot study in December 2014, and the actual in Jan - Sept 2015 with our FY Engineering students, for this I need to look into the existing syllabus and other supporting documents for this smooth running programme, so I am wondering if I could arrange an appointment with you to have an informal meeting, please?

2. Access to Routes to Success Blackboard site - I am also wondering if you could kindly re-register me to access FY Engineering and 1st Year Engineering, please?

Thank you.

Kind regards,
Sevendy Patchamuthu

Mail - Patchamuthu S. - Outlook - Internet Explorer

https://outlook.office.com/mail/deeplink?version=2019090201.07&popoutv2=1

Reply all | Delete | Spam | Block | ···

RE: Arrange for an appointment

You replied on Tue 18/11/2014 16:17

MJ [redacted]
Tue 18/11/2014 15:58
Patchamuthu S.

Dear Sevendy,

I've enrolled you to the Foundation Year Blackboard sites. Unfortunately I have no control over any first year Blackboard sites or authority to enrol, so you'll have to get this from elsewhere, but I know it wouldn't be as simple as enrolling you to one Blackboard: the foundation year is unique in this respect. [redacted] may be more helpful with this than me.

I'm happy to meet with you although, I'm not sure how helpful I will be. All of the course documents are on blackboard, and there are no others. Maybe it would be a good idea to have a look around the blackboard site and if you need clarification or further information, let me know and we could arrange a get-together. You may find that it's all self-explanatory though. Let me know.

Best wishes,

[redacted]

Appendix D **email copy to EFY Module Instructor**

Mail – Patchamuthu S. - Outlook - Internet Explorer

https://outlook.office.com/mail/deeplink?popoutv2=1&version=2019031801.05

Delete ···

RE: PhD Research Participant

Centre for Language Study
University of Southampton

From: Patchamuthu S.
Sent: 20 January 2015 12:09
To: [redacted]
Cc: [redacted].
Subject: PhD Research Participant

Dear [redacted]

Hope all is well.

My PhD research is on 'Critical Thinking Skills for ESAP Engineering: a research into theory, practice and the development of Critical Thinking Skills within Foundation Engineering programme'.

As for the data collection, I will be interviewing the module instructors and conduct classroom observations (to observe students) in the FY programme. Therefore, I am wondering if you could kindly agree to be interviewed for this research, please? Your views and ideas on Critical Thinking skills and FY Engineering students will contribute greatly to respond to the issues under investigation. I am able to provide further details on this if you are interested. Besides, [redacted], my main Supervisor is also happy to discuss this further with you any queries about participating in this research.

I am looking forward to hear from you with a positive feedback.

Many thanks for your time.

Kind regards,
Sevendy

Appendix E **Consent Form**

Consent Form ***(ver. 2)***

Study title: Critical Thinking Skills for ESAP Engineering: a research into theory, practice and the development of critical thinking skills within Foundation Engineering programme

Researcher name: Sevendy Patchamuthu

Student number: 25190288

ERGO reference number: 13639

Please initial the box(es) if you agree with the statement(s):

1. I have read and understood the participant information sheet and have had the opportunity to ask questions about the study.	☐
2. I agree to take part in this research project and agree for my data to be used for the purpose of this study	☐
3. I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected	☐

Data Protection

I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Name of participant (print name)..

Signature of participant..

Date..

Appendix F **Participant Information Sheet**

F.1 Participant Information Sheet - Student

Study Title: Critical Thinking Skills for ESAP Engineering: a research into theory, practice and the development of critical thinking skills within Foundation Engineering programme

Researcher: Sevendy Patchamuthu **Ethics number**: 13639

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

1. What is the research about?

I am Sevendy Patchamuthu, a doctoral student at Southampton University, UK. This research has been designed as part of my PhD project and sponsored by the University of Southampton, and it aims to investigate the existing theory of Critical Thinking skills and Engineering education and how the current curriculum and class room practice address the expectations and learning needs of Foundation Years students in terms of their critical skills to prepare them for their undergraduate Engineering programme.

2. Why have I been chosen?

The research is aimed explore the development of criticality within Foundation Engineering programme, therefore, as you are currently based in one of these universities, you are in a position to provide the most appropriate data for my research in terms of your views on critical thinking skills and practices, and faculty aims to achieve this objective.

3. What will happen to me if I take part?

When you agree to participate in the interview, you will be asked to share your views on the current development and the needs for critical thinking skills in engineering education. The interview will be conducted twice, likely to last between 30 and 45 minutes.

4. Are there any benefits in my taking part?

Your participation in this research will raise your awareness of the current development in critical thinking skills and engineering education in the UK universities. And the data gathered might help you to question and reflect you're your personal needs on critical thinking skills in the undergraduate class. Upon your request, the summary of the findings may be shared with you.

5. Are there any risks involved?

There are no anticipated risks involved in this research.

6. Will my participation be confidential?

This research is conducted by abiding by University of Southampton's ethical policy and thus your participation and the data will remain completely confidential. The data will be stored in a password-protected computer from the start date of the data collection and for another year after the completion of the data collection, and at the end of the study the data will be completely deleted from the computer.

7. What happens if I change my mind?

You have the right to withdraw from the study, without having to provide any reason.

8. What happens if something goes wrong?

In the unlikely case of concern or complaint, you can contact the Chair of the Faculty Ethics Committee at the University of Southampton, Professor Chris Janaway (c.janaway@soton.ac.uk, +44(0)23 8059 3424). (You might need to use English to be able to contact Prof. Chris Janaway.)

9. Where can I get more information?

Should you need further information about the research, you can contact Sevendy Patchamuthu (sp2e12@soton.ac.uk)

F.2 Participant Information Sheet Module Instructor (*ver. 2*)

Study Title: Critical Thinking Skills for ESAP Engineering: a research into theory, practice and the development of critical thinking skills within Foundation Engineering programme

Researcher: Sevendy Patchamuthu Ethics number: 13639

Please read this information carefully before deciding to take part in this research. If you are happy to participate, you will be asked to sign a consent form.

1. What is the research about?

I am Sevendy Patchamuthu, a doctoral student at Southampton University, UK. This research has been designed as part of my PhD project and sponsored by the University of Southampton, and it aims to investigate the existing theory of Critical Thinking skills and Engineering education and how the current curriculum and class room practice address the expectations and learning needs of Foundation Year students in terms of their critical skills to prepare them for their undergraduate Engineering programme in the UK universities.

2. Why have I been chosen?

The research is aimed to explore the development of criticality within Foundation Engineering programme, therefore, as you are currently based in one of the UK universities, you are in a position to provide the most appropriate data for my research in terms of your views on critical thinking skills and practices, and faculty aims to achieve this objective.

3. What will happen to me if I take part?

When you agree to participate in the interview, you will be asked to share your views on the current development and the needs for critical thinking skills in Engineering education. The interview will be conducted once and likely to last between 30 and 45 minutes.

4. Are there any benefits in my taking part?

I hope your participation in this research will raise your awareness of the current research and development in critical thinking skills and engineering education in the UK universities. And the data gathered might help you to question and reflect your personal pedagogical approaches in the integration of critical thinking skills in the engineering/content modules in the Engineering Foundation Year classes. Upon request, the summary of the findings can be shared with you.

5. Are there any risks involved?

There are no anticipated risks involved in this research.

6. Will my participation be confidential?

This research is conducted by abiding by University of Southampton's ethical policy and thus your participation and the data will remain completely confidential. The data will be stored in a password-protected computer from the start date of the data collection and for another year after the completion of the data collection, and at the end of the study the data will be completely deleted from the computer.

7. What happens if I change my mind?

You have the right to withdraw from the study, without having to provide any reason.

8. What happens if something goes wrong?

In the unlikely case of concern or complaint, you can contact the Chair of the Faculty Ethics Committee at the University of Southampton, Professor Chris Janaway (c.janaway@soton.ac.uk, +44(0)23 8059 3424). (You might need to use English to be able to contact Prof. Chris Janaway.)

9. Where can I get more information?

Should you need further information about the research, you can contact Sevendy Patchamuthu (sp2e12@soton.ac.uk)

Appendix G **Student Profiles**

Codes	Group	Gender	Age range	First Language	Language use to socialise	Previous education	Taken English Proficiency Test (IELTS)	Disability
SS01	International (Bahrain)	M	18-24	Arabic/English	English	Private International School (overseas)	Yes – above 6.5	No
SS03	International (Libya)	M	18-24	Arabic	English	Private School (overseas)	Yes – above 6.5	No
SS06	European (Greece)	M	18-24	Greek	English	Bachelor Degree	Yes – above 6.5	No
SS07	European (Poland)	M	18-24	Polish	English	Public Funded School (overseas)	Yes – above 6.5	No
SS08	European (Latvia)	M	18-24	Latvian	English	Public Funded School (overseas)	Yes – above 6.5	No
SS09	European (Cyprus)	M	18-24	Turkish	English	Bachelor Degree	Yes – not disclosed	Yes (hearing)
SS10	British	M	18-24	English	English	State School	No	No
SS11	British	F	18-24	English	English	Private Girls' School (UK)	No	No
SS12	British	M	25-32	English	English	College	No	No
SS13	American (USA)	M	33+	English	English	Bachelor Degree	No	No

Appendix H **Interview Guide**

H.1 Interview Guide – Student

STAGE ONE (Foundation Year – start of Semester 2)

Part A

Warm-up topics:

- Background information; name and age/ home country/ types of education in the past

Part B

Engineering Foundation Year (EFY):

- Experience being an EFY student
- Expectations being an EFY student

Part C

Critical Thinking Skills in General

- Initial perceptions about critical thinking skills
- Experience learning critical thinking skills in previous education

Critical Thinking Skills for Engineering (Engineering Foundation Year)

- In-class practice; which semester/ module provided more opportunity to practice critical thinking skills
- Workshop and lab work; do they provide any support or opportunity to learn or practise critical thinking skills

STAGE TWO (Foundation Year – end of academic year)

Part A

Warm-up topics:

- EFY Final examination – experience

Part B

Critical thinking and examinations

- Critical skills in exam questions – examples from the exam papers
- Critical thinking and scoring in exams
- Critical thinking skills tested in the exam but not taught

Part C

Critical Analysis in exam

- Test construct - technical words/ ambiguous words /analytical words
- Critical skills required during exams – time management/ selection/ relevance

STAGE THREE (final)

Warm-up topic

- Experience having had progressed to bachelor degree

Part A

- Critical thinking and learning experience in EFY applicable in undergraduate course
- Critical thinking – effective way to learn and acquire the skills

Part B

- Critical thinking and language proficiency
- Critical thinking and academic English in the UK university
- Critical thinking and previous learning experience
- Critical thinking and culture

Part C

- Critical thinking skills and assessment
- Critical thinking skills and effective ways to assess students

Part D

Critical Thinking skills now – perceptions and definition

H.2 Interview Guide - Module Instructor

Part A

Warm-up topics:

- Background information; name/teaching experience in general/specialised area

Part B

Engineering Foundation Year (EFY):

- Experience involved in EFY
- Expectations from EFY students

Part C

Critical Thinking Skills in General

- Perceptions about critical thinking skills and EFY students
- Required knowledge skills and critical skills students need to master in EFY

Critical Thinking Instruction

- Definition and pedagogical choices
- Teaching mode – lecture/tutorial/lab/in-class practice/Q & A/implicit/explicit
- Skills – included/excluded

Critical Thinking Skills for Engineering Foundation Year

- Required knowledge skills and critical skills students need to master in EFY

Barriers in mastering the required skills – language/culture/maturity/life or work experience

Appendix I Interview Data

I.1 Interview Stage One – International Group (SS01_M_Bahrain)

SAMPLE INTERVIEW: INTERNATIONAL EFY STUDENT

File ID: SS01_M_I

File Name: REC033-M-I-Bahrain

Keys:

I - Interviewer

SS01 - Interview Participant ID

Interview:

I so, how would like to introduce yourself?

SS01 well, I was born and brought up in the middle-east, born on an island called Bahrain. I live there for around 10 years, and then we moved to Dubai, and we spent 9 years in Dubai before I came here to the Southampton

I so, may I ask your age?

SS01 19

I so, what type of education in the past

SS01 it was like British curriculum when I was in Bahrain I went to British school, and then when we shifted to Dubai I went to an international school and there they did the IB programme, International Baccalaureate a diploma programme

I right. So, this is at an international school?

SS01 umm

I is this at secondary level?

SS01 grade 6

I so, what is grade 6?

SS01 that's the last year of primary

I Last year of primary? Year 6?

SS01 I was 11 years old. Yeah, the high school starts at year 7

I Um, okay. So, 12 years that will be your secondary school?

SS01 Yep

I so, this British school, what do you mean by British school? Was it a public …

SS01 No. No, it's a private school, but it was a, it had the British curriculum like they did the A Levels (_) this is the one in Bahrain

I and this is sort of a private school as well?

SS01 and that was in Bahrain

I right. So, how do you find yourself as an engineering foundation student, being a student in the foundation year?

SS01 I mean it's very different to high school obviously, and the fact that I am so far away from home makes everything a new experience for me. But, do you mean just foundation?

I you mention it's different. So, how is it different?

SS01 well, the cultures are very different, what I'm used to, obviously going to an international school then living in Dubai which itself is an international hub. Going from that to less internationalism, if there's a word? You know one coming here and then adapting to the culture here and learning, I mean the ways that are common here, things like that, and that's what different. As a student, I'm obviously used to at high school classes of maximum 20, 22 students and then coming in the foundation year, walking to the lecture hall for the first time and surrounded by 200 students, that was all very different

I so, the class organisation itself from a small group to a large

SS01 Yeah, exactly. That was a big change

I and that, don't you think even in Dubai, if you enter a varsity the population, the organisation of a class will be a huge as well or are you aware of any kind of …

SS01 no, I wouldn't know of the universities in Dubai, but from what I've heard from my friends, there is 50 may be 55

I umm

SS01 something like that, this is what I heard from my friends, I wouldn't know myself, but that doesn't seem like their lecture halls their classes as large as ours

I umm. So, just now you mentioned about UK being less international

SS01 not less, not the UK but Southampton itself. Majority of my friends were born and brought up here, they're locals, and all are from here, England. Few of my friends are obviously come from abroad but the intensity here is not as much as back in Dubai

I is it because you don't socialise much?

SS01 no, is just that what I come across? I mean for example, in high school I knew people from the all grades, of around 100 students?

I umm

SS01 I knew someone from, like all over from every country Papua New Guinea, South America, North America? Where else here is not as much, majority of my friends are British and others are Europeans. A few are like far-east Asians

I umm

SS01 that's about it

I so, these friends you're talking about, are they from foundation year?

SS01 a mixture of both, foundation as well as friends in my Halls

I okay. How about the learning experience, compared to previous and now? Is there any different or it's about the same?

SS01 I feel much more independent

I umm

SS01 I mean in high school you have teachers constantly checking up on you, whereas here you're given work and it's up to you to do it or not. No one will come around and asking, 'have you done it?'. If there's a deadline you're just expected to hand in the work. No one will ask you, how are your progressing, things like they do in high school

I umm

SS01 so, yeah. I find this different

I so, lack of monitoring?

SS01 I don't think is monitoring as much as they're trying to help you to be more independent, like just telling you how it is, may be in reality. So, it's not lack of monitoring, it's just helping you being more independent

I be responsible?

SS01 be responsible have better time management things like that

I umm. So, sort of being responsible of your own learning? Right, umm. So, this going to be sort of, I don't know how you'll take it, but you can always try. So, what are critical thinking skills for you?

SS01 [laughs] like, how do you mean?

I so, if you were to explain, okay this is what entails critical thinking skill, so how would you define it, personally as a student now…

SS01 umm how would I…?

I you don't have to like sort of refer to a scholarly view

SS01 Yeah

I as a student…

SS01 how I see?

I yeah

SS01 so, what's expected of me when I'm asked to think critically?

I yes

SS01 I'd say, well, you get a wide, I mean a good idea

I umm

SS01 of the problem you're facing

I umm

SS01 and then, I'd say you break it down into parts and then you look at each part individually

I umm

SS01 and you go into more depth, and that way for me that's critical thinking because you're going into more in-depth allowing you to understand the problem a bit more?

I umm

SS01 therefore, coming out with efficient solution for it. To me that's critical thinking

I that means a big chunk

SS01 yeah

I you break it up and then you analyse it in-depth?

SS01 Yep

I of each pieces or…?

SS01 each piece

I and then what?

SS01 fit it into one piece of chunk again

I umm

SS01 that's for me that's what I would do

I so, what would be the word to describe the whole process, because you're using lots of word to describe … If you were to, I mean that's good. That means you're very clear about what you're saying?

SS01 uhm

I but, there are some words which are critical …

SS01 Yeah

I where you can use those words, and it means what you've just said. That big thing you break into pieces, what is the word?

SS01 ah (_) divide? (laughs) did I just said? Ah (_)

I Yeah, that's absolutely a good thinking skill, that's critical skills, but there're actually some critical words when you use it means that

SS01 analyse may be?

I umm, when you put it together?

SS01 ah (_)

I s…?

SS01 I'm lost

I so, it's analyse, you break it into pieces

SS01 oh, analyse

I and when you put it back is synthesise?

SS01 oh, synthesise

I so, usually what happen is, it's easy to say critical, what is critical?

SS01 uhm

I it's a vague word isn't it?

SS01 Yeah

I so, the idea is, for example it is actually breaking up big chunk and analysing

SS01 yeah

I so, synthesise is putting back everything together

SS01 okay

I so, for you critical is about analysing and synthesising, can I say that?

SS01 yes

I so, did you have any experience learning this skill?

SS01 uhm

I did you have any experience learning critical thinking skills in your previous education? If yes how, and if no, why you haven't had the chance to learn the critical thinking skills you think?

SS01 you mean like…

I in your previous learning…

SS01 how?

I yeah, like a module

SS01 ah!

I like critical skills as a subject…

SS01 if we were taught what critical thinking is?

I yeah

SS01 err… we weren't taught as such. It was sort of implemented [incorporated?] in all of the subjects we took in high school

I umm

SS01 there wasn't such, 'okay, this is critical thinking and this how you meant to carried it out'

I umm

SS01 it was just implemented

I umm

SS01 in the subjects we took, so I guess

I umm, so it was incorporated, yeah?

SS01 yeah, I guess we're doing without us knowing that we're doing it

I but you know you're doing something challenging

SS01 yeah

I your know it's not just a normal…

SS01 we knew that, but we didn't know that it was critical thinking

I umm, give me example of things that you've done which…

SS01 well, I took economics at higher level in high school

I umm

SS01 as part of my [IB?] programme

I umm

SS01 and that involved lot of critical thinking because you have to take into account various factors and how they affect the problem you're trying to solve?

I uhm

SS01 so, that's how you have to take a problem like I said, break it up, analyse it and then synthesise it

I umm, so sort of identifying contributing factors?

SS01 exactly

I umm

SS01 and then, their affects in the short terms and long terms things like that

I umm

SS01 yeah, that's an example for economics

I umm

SS01 yeah, we're doing it without knowing we're thinking (laughs) critically

I so, it's more of implicit, yeah?

SS01 yeah

I implicit approach?

SS01 yeah

I okay, good. So, how important do you think critical thinking skills are to engineering foundation year students?

SS01 I would say obviously they're very important for us

I umm

SS01 umm, as because, I'm trying to say the word correctly

I but, you think it's important?

SS01 I do believe it is important because…

I how important? if you were to give a figure, a percentage on it?

SS01 a percentage?

I yeah

SS01 I would say in the 90's probably because…

I very important

SS01 yeah, very important because as foundation year students, we haven't sort of, you would say being introduce to our actual degree. You know next year is when we actually start our proper degree. So, critical thinking will obviously help us to understand how we're meant to approach and solve problems in which we'll face next year

I uhm

SS01 for foundation engineering student critical thinking is very important as it preps [prepare?]us for next year

I as a preparation, yeah? Right, next we're going to move on to critical thinking skills specifically for engineering because critical skills they're very generic when everybody chose to use them, or chose not to use them?

SS01 uhm

I and there's also critical skills very subject-specific, we have engineering, medical, law, business like just now you mentioned about economics?

SS01 yeah

I so, people use critical skills in a different context

SS01 uhm

I so, how a humanities student approach a task could be different from how an engineering student approach the same task?

SS01 yeah

I so, now the questions will be directly relevant to engineering critical thinking skills, okay? Right, so, in which semester, one or two do you think you had more opportunities to learn and practise critical thinking skills? Is it semester one, two, both or none?

SS01 for me personally, I would say semester two

I umm

SS01 because semester one is just me adapting to university life?

I umm

SS01 so, maybe I was probably doing things without realising [how?] it was?

I umm

SS01 in semester two I had settled in in a way. I knew what to do and when to do things like that, that's when I had the chance

I so, is it because in semester two, you've the knowledge already, the content?

SS01 yeah

I and now you've to challenge the theory, or something?

SS01 yeah, exactly, err yeah, in semester two I did for example more reading into our topics which sort of what helped me solve the problems in better ways. Whereas, in semester one I would skim and then try, attempt the problems and then I find them very difficult. So, yeah , I would say semester two definitely

I so, you were adopting easy way in semester one?

SS01 pardon?

I you were adopting easy way which didn't work is it?

SS01 (laughs)

I right, okay. So, you realised semester two is more challenging, which actually challenge your thinking than semester one?

SS01 yeah, personally, yes

I and semester one is more of a adapting to university life, yeah?

SS01 yes, and not really, well I mean focusing on work but not as much as semester two

I umm, okay right. So, in your opinion which module or subject in the engineering foundation year provided you more opportunities to learn and practise critical thinking skills and why this module is better than the other, if there's one?

SS01 err [_]

I	of course, all the modules have something going…

SS01	yeah

I	but, there must be some modules which have something more than the other?

SS01	for me it was Mechanical Science, because the thing about Mechanical Science is that you have a set of formulas

I	uhm

SS01	and from those formulas you can drive new formulas, and these formulas can be applied to various problems. It's not like you have one formula, it can only be applied to this topic, you can apply to different sub-topics

I	umm

SS01	so, that's why for me Mechanical Science helped me to think like you can say outside the box more critically, because you'll look at a problem, you would, I would see what I'm given, [this is where I decided to analyse?]

I	umm

SS01	I see what I'm given, what I need to find and then what formulas I can use to find that

I	umm

SS01	sometimes I would find that if I need to find for example X, I would need to first find A B C than I would get X

I	umm

SS01	with that, this is why I always split up my problems individually and then once I have the (variables?), the components I need I would synthesise

I	umm

SS01	and then I find the main [factor] that I need to see

I	umm

SS01	so for me Mechanical Science was where it helped me to think critically more than the other

I	umm, this practice was it in the class or was the practice on the Blackboard [VLE]?

SS01 it was, in class. We were given a brief understanding of it and then when the worksheet came out …

I understanding of what?

SS01 of any topics of what we're learning

I content?

SS01 yes, and then when the work sheets came out, we attempted the worksheets that's where we found that you have to use, and the workshops helped a lot because there were some questions just, we found them difficult and then when we went to workshops

I umm

SS01 we saw how the professors solved it and then we're okay it's not just a one step process, you have to do various things

I umm

SS01 and that helped a lot because we understood that you won't find the answer immediately. You have to do, you have to play around with the formulas first

I right, okay. Now, besides the lectures every students in foundation year is given opportunity to use the support classes?

SS01 yes

I and, just now you mentioned about workshop sessions as well, so have you attended the workshops or support classes? If not why or if yes, do these workshop sessions encourage you to be more critical?

SS01 I've attended almost all the workshops

I uhm

SS01 because I've found them more helpful, where else the support classes maybe not so much, maybe up to the first month of the year

I uhm

SS01 because everything I needed to know I would find it in the workshops

I uhm

SS01 so, I haven't really attended many support sessions. I found the workshops were more helpful

I so, why is it the support classes were not helpful?

SS01 it wasn't that, it was not that helpful. Many of my friends found them very helpful. It was just that what I needed to understand I got it from the workshops

I umm

SS01 so, I didn't need to attend the support group

I so, because of the workshops sort of compensated to the…

SS01 exactly, and the workshops I found them, there were two umm [_]

I PGTAs?

SS01 PGTAs there, and they can get around to you faster

I umm, so, usually you know each PGTA, so, what's the ratio like in workshop? how many of you usually at a time?

SS01 it really depends on the module

I umm, generally?

SS01 for Mechanical Science it was around ten of us ten, eleven

I umm

SS01 and we had two PGTAs, which is,

I okay

SS01 obviously not everyone needs help in the workshops, so the ratio to the people that needed help to PGTA was better

I umm, okay. So, this questions will be based on PGTA. Now, apart from support classes students also provided with PGTA assistance?

SS01 yeah

I so, what are their roles? Do they provide any supports or opportunities to practise your critical skills?

SS01 the PGTAs themselves?

I umm

SS01 they do when we need assistance. They do talk through the procedures and explain as well as give us the chance to ask questions of why they're carrying out certain steps. So yes, I'd say the PGTAs are quite helpful

I so, they also help you to answer the question 'why'?

SS01 yeah

I umm

SS01 why they're doing certain things

I so, they also like, once you're given the opportunities to respond to those questions they're already encouraging you to be critical isn't it?

SS01 yes

I umm

SS01 because when you ask why they give you first obviously the background and then how that applies to the problem which helps you to think that way for the following problems?

I umm

SS01 so yes, in a way you're thinking, they do help you think

I is there any specific workshop that you incline to say that you had more from that particular workshop?

SS01 again, for me it would be Mechanical Science

I okay

SS01 that really helped me to think critically because of that

I okay, so as a student in the foundation year in what aspect do you think that you had more opportunities to learn or practice critical skills, like being a student in the foundation year you have lectures to attend, your workshops, support classes, you do course works individually or group work

SS01 uhm

I like the computer application?

SS01 yeah

I you also have personal tasks like doing the worksheets for every week sometimes, 'EE' you have that don't you?

SS01 uhm

I and then attending workshops and other, so you have all these choices which one you think, sort of like talking about independent learning and you're trying to solve problems by yourself, which one actually gave you more opportunities to practise your skills?

SS01 my critical thinking?

I umm

SS01 it would for me would be the worksheets that we got every week

I umm

SS01 the lecturers do help, they give you a brief understanding, the lecture notes were good as well, but in order to actually apply what we've learnt

I umm

SS01 I'd say for me is the worksheets definitely

I umm, so, you benefitted more on doing the worksheets than…

SS01 yeah, in order to think critically

I okay right, thank you

SS01 is that it?

I yes, thank you very much for participating

I.2 Interview Stage Two – European Group (SS08_M_Latvia)

File ID: SS08_M_EU

File Name: REC016-M-I-Latvia

Key:

I - Interviewer

SS08 - Interview Participant ID

STAGE 2

EUROPEAN EFY STUDENT

File ID: SS08_M_EU

File Name: REC030-M-EU-Latvia

Keys:

I - Interviewer

SS08 - Interviewee ID

Interview:

I so, how was the exam?

SS08 they were fine, but comparing with the ones, previous three years they made it more difficult except the Mechanical Science. That was still pretty simple, but I wouldn't say they've made substantial changes but they were definitely difficult and definitely more time consuming especially EP and Electronics

I umm

SS08 they were no way I could finish it in time

I umm, so, why is it difficult? How do you know it's difficult?

SS08 I wouldn't say very difficult, it's more difficult in comparison with the ones they had in the previous years because we, what we did was went through all past year papers

I umm

SS08 except the ones five years older or ten years older, I didn't do a lot of those because I presumed they would be more similar to those now

I umm

SS08 because the division of points for each question was not, a little more different like between sections, like previously it could have been fifty-fifty, but now it's like forty sixty, and so on

I umm

SS08 and also like I can indicate to you some small changes, for example in Maths there were, it was not that difficult It's just Maths was fine, but there was like new combination which I had never before like, for example you had [two impulsive?] partial differentiation

I umm

SS08 although I only had regular partial differentiation or (successive?) partial differentiation, so it's an example that I've never tried before

I umm

SS08 and in EE, in Electronics I would say the first part, was basically that (compulsory? 2:21.8) was the same

I umm

SS08 but the section part was a little bit more complex than the previous years. Plus they, like for example I would say that I presumed that if, like we have a question about a [transient or something?]

I umm

SS08 then it would be more theoretical or maybe would be just about thermal (couple? 2:48.0) or something where you have to explain like five percent question, but it turned out specifically the one topic that I did not revise was a twenty percent question (laughs)

I umm

SS08 so I lost quite a lot on that

I so, that's Part B isn't it?

SS08 Yeah, Part B

I umm

SS08 It was fine. Its just that they did try to amplify that difficulty, but mostly due to the fact how much time took to do everything because the previous year's exams, the previous years in Electronics you could do the exam in time this year's you could not

I umm

SS08 I mean it would be possible if you knew perfectly everything and you didn't have to like take time to remember something or to figure out how to get something, then sure you can do that in few hours but not in any other way

I umm, right based on all the questions in the exam that you have attempted, how many questions do you think that you needed critical thinking skills to answer?

SS08 ah (_)

I were you aware that when you look at certain questions you realised you needed critical thinking skills?

SS08 ah, I would say maybe around like forty percent required critical skills and may be half from those forty percent required them to the extent that where you really have to think on your own

I forty percent you would say?

SS08 like I would say forty percent because…

I over all?

SS08 okay, may be this year exam is a little bit higher may be fifty

I umm

SS08 fifty to sixty percent

I umm

SS08 I would say this year. May be in the previous years, the thing is in the previous year's exam there were many repeating patterns

I umm

SS08 and past exams when I talked to the lecturers this was exactly the reason why they made the changes in EP, in Maths and in Electronics because there were repeating patterns and the questions were pretty standardised

I umm

SS08 so it wasn't difficult for me to do them because I just targeted doing them automatically like automatically knew what cause of action that I should take when they start changing things like they change the set-up of the questions even though they are based on same knowledge, you start to question what you have to do. It means you automatically have to go through everything that you know

I umm

SS08 and you have to analyse more and you become more doubtful

I umm

SS08 so, okay…

I so, can I say the previous past questions, previous year's past year questions you could do it mechanically, that means you know what…

SS08 after two to three examples, yeah I would be able to do it automatically

I umm, but this year it's a bit difficult?

SS08 yeah, I would say that the, for EP the second section is more, definitely they made, the biggest differences were in EP for the second section. For the second section I just feel that they didn't change it as much

I umm

SS08 but, even like slight changes for let's say for its tasks it means it will be more time consuming, because the thing that I was shocked was not so much of the difficulties but how quickly the time passed

I umm

SS08 because when I reached like the end of question nine I was only left with fifteen minutes and I have at least like at least thirty five of content left

I umm

SS08 and it was impossible for me to do it in fifteen minutes, and that was like a shock to me, so every next exam is better for me

I umm

SS08 except for the very last one which was Electronics because that also required a lot of time, but I felt I was better prepared for that

I so it looks like you had more problem in time management, then?

SS08 yeah, I would say so

I umm, **so which of the modules in your opinion required more critical thinking questions?**

SS08 ah, that's a bit difficult to answer I would say that, you're talking specific about the exams?

I yeah

SS08 okay, they were more equalised, I think. Last year for example in EP it didn't require critical thinking skills almost at all

I umm

SS08 this year in the second half it did, but I think In EE the most, I would personally think

I umm

SS08 in EE the most

I okay. So this is the third question, so do you think if you have the critical thinking skills would have had helped you to answer the questions better?

SS08 slightly yes, I would say by ten percent margin I would say

I umm

SS08 but for me personally, I think the biggest issue is how long it takes me to do everything because for me it felt more like a speed test, basically

I umm

SS08 especially in Electronics when I did my revision went through a lot of things everything make more or less sense but again I went through it quite slowly

I umm

SS08 and like for example if I had circuit that has a transistor integrated to work as let's say inverting amplifier something like that

I umm

SS08 then, like if you've given to me on face value

I umm

SS08 it'll be impossible for me to explain what each of those components are but if you would put me in a room for two hours and remember the logics of the transistor, then I would figure out what the voltage is in comparison with this voltage, what the (10:34.0?) does here and what the (10:36.5?) does here and if I would see these are the in-puts and the out-puts and what they do

I umm

SS08 then I would in two hours I would be able to explain to you what it does

I right

SS08 but, this is not what an exam is for, the exam is more like a speed test like tests your already familiar with this, not if you eventually be able to figure it out the real answer, so it requires more training

I umm

SS08 it does require critical thinking skills when have to do something that you never had before

I umm

SS08 but, I think in the end it would only have like ten percent impact

I umm, ten percent impact?

SS08 I would say

I right. Critical skills is also about making decision, quick thinking based on certain criteria isn't it?

SS08 also, yeah may be

I so, in making decision, do you think it would helped you if you had prioritised which question to do first…

SS08 in EP definitely, because I started from Section A and I regret that tremendously

I umm

SS08 I should have started from the other end, then I probably gotten at least ten to fifteen percent more

I umm

SS08 so, starting with Maths I started doing everything from the other side, like I actually checked every single questions before I started anything

I umm, so, which was the first module you try first?

SS08 EP

I so you learn from EP to prioritise which…

SS08 yes, because I was so used to the past papers that I just thought, okay I just start with this because I'll be able to do this very quickly, but yeah I did not read the questions, especially the end questions

I umm

SS08 I did not read them before like I would say I don't know like thirty minutes before the end

I umm

SS08 which is a very mistake

I umm

SS08 yeah

I but it did help you?

SS08 I mean it gave me a good lesson for the next exams

I umm, right. Was there any questions in the exam which require specific critical skills which have not been taught or introduce in the class? It could be in any modules

SS08 ah (_)

I requires some specific skills for engineering?

SS08 I would say, I wouldn't want to say definitely no because if you actually go through all the lecture notes

I umm

SS08 then you should be able to do all of the task, so I don't think there's something that, there's something in the questions that was never covered in the lectures or in the notes

I umm

SS08 in the past papers, at least that what I think. I don't feel it would be impossible to do a specific task unless they like extra, if you did extra (_)

I practice

SS08 not practice but research

I alright. So, can I, my question was is not about the questions but the critical skills

SS08 yeah

I so, is there any critical skills when you read a question, is all about doing tasks isn't it, they're asking you to do something? But when you looked at the questions, is there any questions in any modules, it required critical skills but it is something that you're not familiar with?

SS08 oh! Okay, well, there's only actual example which I remember I could give was question nine from EE

I umm

SS08 but the fault was mine because I presumed the likelihood of me having a (thermosets 15:05.3 ?) in a numerical question would be closed to zero

I umm

SS08 but I was wrong because the only reason why I didn't do that question was because I did not remember the characteristics of that specific transient

I umm

SS08 so what I did is that I decided to do it as the last question and I did everything after and before that but in the end I ran out of time and I did not manage to do question nine

I umm

SS08 but the reason why I pushed it back was because I did not revise for that specific transient did. I only remember like okay I understand it should react to change in the temperature but theoretically everything, every single material reacts to change in temperature and its resistivity changes but I did not know how it is different from (thermocouple? 16:03.3) or something else

I umm

SS08 so, I decided, okay I'll do it later if I have the time

I right, so basically what you're trying to say is, but you got to correct me okay? So the questions which you had problem is not the question itself but it's your own personal approach…

SS08 I would say yes

I yeah

SS08 I would also say the things is that, actually this kind of circuit was from my recollection only covered in the notes and we did not like

I right

SS08 I did not remember that we had an explicit example of such a circuit during the lectures or during any assessments before, but we definitely had that in our lecture notes, so I still don't think of it as being something that I was not prepared for. I mean if it was in the notes then I should be prepared for

I umm, okay

SS08 which was interesting, because in EE I'd prepared for, I prepared for transient, I prepared for filters or rectifiers about diodes

I umm

SS08 and lot of that stuff was not covered actually

I in?

SS08 in EE, I think like there was nothing about filters and there was nothing about rectifiers, there's nothing about transistors

I umm

SS08 and I studied about them because I thought that there will definitely be a twenty percent question about them

I umm

SS08 but I didn't study so much about transient it was one day before the exam so I thought I can't like focus on this anymore

I umm

SS08 but

I that came out?

SS08 yeah, that wasn't a pleasant surprise for me personally (laughs)

I so filters, rectifiers and transistors came out?

SS08 so there was nothing about rectifiers, transistors or filters

I oh, okay

SS08 there was typical things like transient (18:09.0 ?), all that was there but it's expected but I did not expect that there would be absolutely nothing about the four types of filters or about rectifiers or about, yes there was one question about diodes but there was nothing about transistors

I umm, right

SS08 but I still think it's okay fine

I right. Now when you looked at the questions, so which questions you found they were quite simple for you? Why did you find those questions were simple for you? For the question that you found it easy for you…

SS08 well, I think…

I could be any modules

SS08 I've already gave reason, that is something that I have done several times before and it feels standardised, so this automatically gives you a mind-set that you take extra (17:27.4 ?) cause of action and you're hundred percent sure that this will give the correct result. Although, it's a bit strange in the first question of EE. In theory I covered very thoroughly but I had the actual example I felt like I actually never got the correct answer and so, even though I understood the logics of it like for example when we use galvanometer as (19:57.0 ?) I understand what's happening there like (20:05.0 ?) you have different voltages and for other is vice versa. But, when I was actually deriving the formula for that I felt as if I got the real answer but when I go back to the theory

I umm

SS08 it feels pretty simple, so that was only hard thing for me personally, but usually the thing is I feel it's easy because it's either, yeah most likely is practice. The easiest one is the one you had most practices with

I umm

SS08 or the theory is simple

I can you give example

SS08 like for example you have to explain why the current can only flow in one direction through a diode

I so question on explaining something is easy for you?

SS08 yeah, I think

I so what type of preparations you do to answer questions on explaining or describing something?

SS08 ah, can you repeat that question?

I so, for you question on explaining on something is easy for you? For example a question on explaining a specific theory?

SS08 yeah

I you personally find it easy to handle those kinds of questions?

SS08 I think so, yeah

I so for you to prepare to answer question which requires you to explain something what do you do?

SS08 the theory is not difficult for me to not memorise the most important bits of it because once you remember the most important bits of it you can easily like draw the connection between them, okay if this is dealt negatively and that dealt positively then most likely if it is positively dealt, yeah it will have (hold 23:50.8?) that is positively charge

I umm

SS08 and if you have a circuit that is positive and negative terminal, then when you remember which direction it flows then you will quickly get to the conclusion to why it would work in that way but if you switch the terminals then it wouldn't work in that way

I umm

SS08 like it's so simple that you cannot fail I think

I umm, right. So, for questions which require you to explain something, the technique you'll adopt is memorise?

SS08 for theory I would say yes, I mean of course unless you're, I don't know describing, like something like (sea back? 24:40.6) effect or something like that if you've something related let's say especially in EP there was a theory which was just based on a formula

I umm

SS08 if just look at the formula you can just intuitively draw the conclusion like you could basically explain the theory by just looking at the formula especially in the EP, in other modules not that much I would say

I right, so how about difficult questions, why a particular question is difficult for you?

SS08 because especially under pressure, I started doubt my judgement if it's something correct or wrong because (_)

I pressure on what?

SS08 time pressure

I umm

SS08 not doing in time is the biggest pressure that I could have, not doing in time

I so it affect you confidence is it?

SS08 yeah, because if you have time it means that you can actually go through two scenarios, let's say if think this component works in this kind of way or let's say the potential differences

I umm

SS08 in here you think they're smaller than you think or bigger than you think like work out through both these scenarios then you can see which more, which one is more logical and then you go with the one more logical and then obviously you can make a better conclusion. Of course! under time pressure you don't have that kind of privilege

I umm

SS08 you have to right with first guess

I so, you only find the question difficult, you correct me okay because I shouldn't use the word only, **mostly you find a question is difficult when you have time pressure?**

SS08 I would say yes…

I so how about…

SS08 of course if you know all the theories, because I believe there's only a handful of questions that are like really difficult in the respective modules throughout the whole year like in MS there's this specific question in the end I was not able to do and that turned out to be like the most difficult one. It was about dynamics, like a rolling board which was initially was static but it was hit…

I was this question in Part B?

SS08 no. not this was not in the exam, back in the…

I pass year's exam?

SS08 no, it was not in the pass year's exam it was in one of the problem sheets because I really doubt that they would have such a question in an exam because it would be a little bit too difficult and too time consuming

I right, **apart from time pressure what else you would say a question is difficult?** You said time pressure and you also mentioned you need to know some theories as well…

SS08 more or less, yeah

I that's knowledge isn't?

SS08 if you have gone through the theory and you have had enough practice then all of them are fine, if you, let's say you take out the non-standard question like in B Section I would say that like for example in Electronics like twenty percent of that points that you can get were based on something that was really non-standard. And, I could say that may be this is like the average, except for the MS, MS was pretty simple, if you actually did all the tasks and you memorise how you did these tasks

I umm

SS08 you can easily get ninety or more

I so this non-standard, what do you mean by non-standard require more…

SS08 non-standard is something that you might have done may be once but not more often than that

I so this requires more thinking?

SS08 yeah, it does

I so **how about the wordings in the question itself?**

SS08 umm, it was fine

I umm

SS08 except I messed up in MS which cost me like fifteen minutes that's one, it was about an object that was rotating around an axis but I presumed it was rotating like a vertical pendulum

I umm

SS08 but, when they gave you a question and analysing the forces that I'm working with it didn't make sense for me. How can they ask me to give this if they work in that kind of manner like you have (29:39.4 ?) like this doesn't add up in that sense, but then at the very end I just left it like EE

I umm

SS08 in the end I just went back to it and I realised it's not rotating like this and it was rotating like this (hand gestures was used to show the movement), that changes everything

I umm

SS08 (laughs) it cost me like fifteen minutes like and I felt like an idiot

I is it you said a pendulum?

SS08 like a vertical pendulum, but it's not like this (hand gestures used) it's vertical or one rotating around the axis, and I should have, I think I read through it once or twice. But, I figure it out by the fact that it doesn't make sense because in the end I thought okay, this also mean it's actually rotating around a horizontal axis and then it would make sense to why it changes the velocity because you have the gravity working against it and then (30:39.5?) working in favour it at the bottom. So, it would make sense why the velocity changes

I right

SS08 so I realised that I made a mistake

I umm, okay. Right, you worksheets on the blackboard which you could practice prior to the exam?

SS08 yeah

I so, looking at the worksheets, the questions that you've attempted were they a mirror reflection of what came out in the exam?

SS08 I would say that for example specifically for MS, I think that it's quite valuable because they certainly have questions that are more difficult that the ones you get in exams

I umm

SS08 so that's quite valuable, but also at the same time it gives you like some questions are less numerical and more abstract where you just need to understand what forces are working there. For example, you have to derive a formula for …

I this question is on worksheets or exam?

SS08 in the worksheets

I yeah

SS08 but you might have to do similar tasks

I yeah

SS08 in an exam, like in the past papers I found like some examples,

I yeah

SS08 the worksheets, but the worksheets also have more difficult questions than the one you would get in exams and I also think a good thing

I so, it’s quite a good balance do you think?

SS08 yeah, for Maths

I umm

SS08 I would say that by part it’s valuable because they also have some examples that are more difficult than the ones in the exams

I umm

SS08 but at the same time I felt like, I still felt like there were somethings that were new to me

I umm

SS08 in Maths exam for some reason

I umm

SS08 I gave you one example, but I had that feeling throughout the whole exams for some reasons I don’t know

I what, Maths exam?

SS08 yeah, I had such feeling even though I went through everything, like I went through task sheets with certain amount of confident like I felt think kind of still felt unusual for me when I through the Maths exam for some reason

I umm

SS08 there were a few questions that I felt non-standard to me

I right

SS08 and I felt Maths sheets did not prepare me that well enough for something non-standard as in MS for example

I umm, so the term non-standard you use means more challenging?

SS08 ah, may be in some cases but not in all cases because non-standard might be also something that is not difficult but it was not asked from you before, like for example in the past papers you would usually like differentiate something using the first principle or something like that. But then, they just gave you something that is extremely very simple question like how you would differentiate this

I umm

SS08 but, it doesn't give you like a specific formula, like it just give you a general question and then you feel like what I'm supposed to do here?

I umm

SS08 because (laughs) you never had like give general answer or something, you just automatically deriving at something

I yeah

SS08 it not necessarily be difficult, it's just non-standard

I so doesn't fit the standard pattern?

SS08 yeah, that's what they try to do, they try to make non-standard as it was before because, especially EP. I would, I completely understand why they change EP because it was too easy

I umm, right. So, **as an engineering foundation year student do you think if you've acquired essential critical skills for engineering would have helped you to score, to perform above average?**

SS08 okay. Above average, I still, above average, I still have to wait for the results for twenty days I think? Yeah, twenty one days, ah, critical thinking skills definitely give you advantage but I would say fifteen percent at least

I fifteen?

SS08 ten to fifteen percent. Of course, I mean if you're not going to do the revision, and you're not going through the theory

I umm

SS08 and practice, then you obviously you're gonna fail, but I think if you do practise and you go through the theory even without critical thinking skills you can still managed I think. But, this year it would be like, it would be a little bit uncertain whether you would be able to average out above sixty

I umm

SS08 if it would have last year then you would be able to pass without any sense of uncertainties but this year if I think it's little bit more challenging

I umm

SS08 I think it's a good thing

I yeah, so can I say that compared to, because you've had been doing lot of practice on past year exams…

SS08 I would say that, I should, I could have done more practice

I umm

SS08 to be honest, because especially for EE

I umm

SS08 and Maths may be, I think I could have taken more practice

I umm

SS08 I actually made some stupid mistakes in MS, ah like for example with the linear, conservation of liner momentum in certain vector

I umm

SS08 not just in general, because in general then you have to take into account both the vectors, but, so I made stupid mistake where I might have lost quite lot points there, but I still feel that it doesn't matter that much because I will still pass and as long as I understand everything is there it doesn't matter

I umm

SS08 I just need to understand everything and I need to pass because my score doesn't matter

I umm

SS08 but in Electronics and Maths I feel that I should have taken more practice. It's just my laziness, I started so late for revision. Like for Electronics like seriously like only four days before the exam

I umm

SS08 and I went through the theories two days I think, but I was too tired to go through transient in details because it's like transient was like fifteen pages of theory

I umm

SS08 before that you had like, oh! No transducers like the only thing that I really too lazy to revise, I paid the price for it

I umm

SS08 if I've reserved like a whole week for Electronics, then I might have scored at least ten percent, ten to fifteen percent more, but it's due to my laziness, I think

I umm, so it's more on the preparation

SS08 yeah, definitely, the content here is definitely preparation. Just today I started to looking at the papers on the tasks that I might do for the exams next year

I umm

SS08 there gonna be more theories involved, and I think I'll start my preparation very early. I talked to another girl just after the exam I think she's an older student and she has been living here more than ten years and she has not studied physics I think before

I umm

SS08 and she told me that she would be preparing for this exam at the very beginning of the year, and I'm thinking that actually that could be a good idea

I umm

SS08 because it would be easier to make mistakes in next year than this year

I umm, right. So, this will be last question

SS08 okay

I if you try to recall all the questions that you might have read there might be some key words which had helped you to answer or understand the question?

SS08 yeah

I before you attempt the question, right? So, what were the key words in the question which would actually indicated critical thinking skills in the exam papers?

SS08 I'm not sure if I even can answer that because critical thinking skills were not that much connected to how you phrase the question

I umm

SS08 it was more about how the question was set up instead, for example let's say finding the resonance to between two tubes instead you would have two tubes filled with materials like it's stuffed with materials and each time it resonate it becomes, the volume that it fills become smaller and smaller

I umm

SS08 and if you have never done that before then you need to start working with your brain, so what happening there

I umm

SS08 and for example also, just a five percent question in Electronics, instead of let's say getting the transfer function from the circuit that resulting voltage, instead they give you an equation and you've to draw a circuit by yourself by considering the given equation which is something that I didn't see in the past papers

I umm

SS08 so it's the same theory but they completely turned around the sequence of the action that you need to take, it's reversed

I right. So, if you were to give me some words if you find them in the question, the words are verbs, the action words, so, what words you would say they mean you got to be critical? For example, you have words in a question like describe, explain those kind of words

SS08 I think in my experience when there's question says describe then it doesn't require that much of critical thinking skills

I for what?

SS08 I stand corrected actually, ah, when we were talking about the five percent question, then it's definitely simple, but when we're talking about a more elaborate circuit, then obviously it's more complex

I right

SS08 so, it's always like, it's very changeable for me I don't look at some specific words and deciding whether it provide more critical thinking skills than the other question. It depends on the content and tasks

I right, the overall content?

SS08 yeah

I not specific words?

SS08 yeah, at least I did not notice

I okay

SS08 correlation between these two

I right, okay. I think that's the about it

SS08 yeah

I thank you very much

I.3 Stage Three Interview – UK Group (SS10_M_UK)

File ID: SS10_M_UK

File Name: REC_Voice084

Key:

I - Interviewer

SS10 - Interview Participant ID

STAGE 3

BRITISH STUDENT (UK)

Interview

I has your perceptions towards critical thinking skills has changed or remain the same since FY

SS10 I think it has changed. Previously I thought critical thinking skills were more related to mathematical skills and it's actually language based problem solving. So, applying the features of maths and thinking around mathematical way to solve them I had to think differently about them. I think now I'll take more pragmatic approach to critical thinking.

I umm

SS10 let's say it's less about, sort of abstract thought processes. It's more about interest in finding an answer in many a times. So, particularly in engineering, just doing a research, finding out what you need to know you need to really apply lots of critical thinking. It's a bit more of finding the answer and, yeah, that's it. It's little bit more down to earth.

I is it surprising, or is it what you expected to happen now. I mean foundation year is more about transition period isn't it from your 6th form or high school?

SS10 umm

I you try to get adjusted to the university system, so you're already like more than a year now?

SS10 yeah

I were you fully aware the changes will happen, or did it come as a shock?

SS10 no, I think it came as a relief, it what was expected to be honest. I was expecting it to be little bit, I was expecting far more things. I didn't understand like in any way, things were beyond me, but, it turned out that it's not quite like that. I can understand the stuff, it takes work obviously, but there's nothing, which actually like beyond my understanding

I alright

SS10 it does seem oddly less complex than I figured that it would be, which is a good thing

I less complex than you thought?

SS10 yeah, lot less

I right

SS10 the jump in understanding isn't huge and certainly the application of critical thinking is very much the same sort of thought processes, just apply a little bit further, more in-depth. But, nothing incredibly new or nothing that shocked. It's quite a relief!

I okay. In your opinion is critical thinking important for engineering? If yes, why and if no why? What's the reason for your answer?

SS10 I think it's important, but depending on how, what sort of engineering you're doing. Obviously, it's not like one thing, but if you just solving problems will then probably you won't have to do a lot of critical thinking because most of the problems have been solved before. You could, you just need to apply a little bit to other solutions of what you're doing

I umm

SS10 of you're trying to do new things then you need critical thinking, which I suppose go against what I've said earlier. What I thought critical thinking was, yeah, may be. I still don't fully know what I mean by critical thinking is to be honest. But, yeah, may be in the abstract sense like thinking new things, thinking differently. That I imagine is useful in engineering, and I perhaps got a hint of that in the stuff we've done in the course we've done so far, when you try to think of new things

I this news things, are you referring back to the foundation year or now?

SS10 I think now, for sure. We've a little bit of leeway to do sort of the stuff that we want to do

I you've more freedom now?

SS10 yeah, little bit, not much, but…

I right, okay

SS10 but, you know when you get to design some things, projects that interest you here and there

I umm

SS10 then you have the chance to apply critical thinking to trying to look at things differently, come up with new stuff. If you just try to solve problems there're plenty of engineers, my dad was an engineer. Lots of engineering just you know, you don't have to think like new stuff in imaginative ways. You just try to solve problem which has been solved many times before just with new numbers

I right

SS10 yeah, it depends on the sorts of engineering that you're doing whether you need critical thinking or not, it is important

I like for yourself you mentioned you've chosen mechanical engineering?

SS10 uhm

I so how important it is?

SS10 for mechanical?

I yeah

SS10 I think more important than it is, probably for any sort of engineering

I can you give an example, how is it important?

SS10 the way it's important is the same way for all forms of engineering, try to think of new things, develop a new thing, but mechanical is more so, because mechanical is so broad

I umm

SS10 so, there's more application of critical thinking, you know it's equally important to have critical thinking skills especially if you're doing aeronautical or electrical engineering, but your application for that considerably more narrow. So, you're applying to [playing wing?] or something, or circuits. But, in mechanical it could be that and a whole bunch of other stuff, the whole point of mechanical engineering is that it's very broad

I can you give some specific examples

SS10 in terms of critical thinking?

I yeah

SS10 no, I couldn't give you specific examples

I you couldn't? how about something almost similar like in your mechanical course?

SS10 (laughs) Well, I suppose code is a good example, coding

I coding for?

SS10 I would code to create (_) So, it's just mechanical has more critical thinking, I would just say it's hypothetical, I don't actually know, I would just suggest that, but probably true. But, yeah, that's why I couldn't give specific example. At this stage all of us are doing the same course. First year is same for everyone. I think second years slightly similar for everyone, the third year then you start doing mechanical engineering, aeronautical engineering that sort of thing

I what would be the effective way to develop the skills

SS10 as for the past couple of weeks I've been sort of thinking, sort of it occurred to me, or the only thing in terms of critical thinking I would say that the most important thing is languages and in every sense that you can mean language. So, obviously spoken language, that itself is an exercise of critical thinking. You're taking different inputs, you're getting different responses from the people and you're coming back that you sort of and we do it very well. It shows anyone is capable of critical thinking, I think. Spoken languages is a small example of that and that's quite an important one that we take it for granted. But, in terms of engineering, the language is Maths and also code, so what you really have to learn is how to be fluent in Maths and be fluent in code. If you could do those, there's no strict solutions, well there are obviously, but there are no strict applications. They work for anything, that's the beauty of language. You know, I will use the same Maths in trying to explain how gravity works that I used to explain all sorts of simple things like you know, 'stress,' and, 'strain', that kinds of stuff. So, I think to become fluent in the languages, and now I can represent what I do mathematically using code, you know that sort of thing. So, I think by learning those that's the best way to learn critical thinking

I did you have enough practice on foundation year?

SS10 they did a great job of facilitating questions, so there was tutorial and stuff, where we set questions by weekly basis, I think, whole bunch of questions. It was for every modules, though there're slightly less for some of them, but every modules have regular questions, and that was great. And, they also gave tutorial sessions where you can go through the questions with the teacher when you don't understand something, so yeah, that was great, and they did a great job for that

I so, in your opinion do you think it's important to assess engineering students critical thinking skills as an exit test?

SS10 Obviously in the term of the society now, you think you have to have assessment. Just being a realist need to have assessment, otherwise, I mean how do you know who's good at what, you know? So, you have to have it. That seems to be some sort of matrix, but whether it's actually benefit critical thinking skills (_) So, I think it this way, using coding again, so this is like my matrix to critical thinking. How do I code something like that, that's me. Like thinking of random new things and I enjoy it, that sort of things. I'm getting, I'm good at code now, I'm getting good, getting better and doing well at it because I'm taking an interest independently the course and the stuff that we're assessed on, fair enough you need to get to the (18:55?) of what we're doing so that we understand the basics. But, in terms of critical thinking I got good at using code now, because I'm doing the stuff that's not assessed. I just do stuff that I enjoy doing

I alright

SS10 again, I guess interest, just taken interest, that is not a sort of thing you say in a course I got interest, but yeah, that's what I can think of

I so, do you think students need to have high command of academic English for them to acquire and develop critical thinking skills?

SS10 no. Because I think critical thinking is independent of what language it is. I reckon, you can take yourself, born and raised let's say Malaysia and he doesn't, obviously speak English may be, he could be considerably better as a critical thinker than anyone who's fluent in English. But, it's just that they can't write down those stuff in English that does not mean he's not a critical thinker, in my opinion. Yeah, having a good grasp of English isn't necessary, but obviously if you try to work in England just like the pragmatic thing, yeah, you need to have a good grasp of English

I how about written English?

SS10 I think, it helps in written and reading, because verbal communication is important when you're dealing with people, obviously (_) when you're trying to give your engineering work to your manager or something. If you do group work or something

I so, does that affect the way students acquire the critical thinking skills, or is not?

SS10 I think language is critical thinking, it's just sort of manifested as a language so, where maths is clearly which is very quantifiable way of critical thinking, code is just represent that, it's just that maths is more of a visual way than spoken language, and I think critical thinking is just applied in a different way. It's the way you could express critical thought, I think

I so, in order to express critical thought, which you've interestingly mentioned, do you think students with low level command of English will excel in this?

SS10 yeah, they just do it in a different language, in England, no. If you're talking in terms of critical thinking generally?

I no

SS10 yeah, it would be useful to have a good grasp of English. Worth bearing in mind, I'm an English speaker, brought up and speak English and I don't speak any other languages, so, probably I'm the worst person to ask the question to (laughs). Because, I don't have problem with it. It's fine for me, speak English, read English, write English…but, it doesn't matter if it's maths. I think, I probably say, on the whole, to be honest you probably find the statistics for, I just be saying like an anecdotes, generally those not having it as first language probably do better, I imagine. But, again that's just …

I does you first language, culture and previous learning affect your critical skills in academic context?

SS10 I take it for granted that I can understand lots of the terminologies and stuff, when come to using like new words, basically. Engineering words like long ones which is difficult and stuff I find that, if that were to influence my critical thinking that wouldn't be a problem because I'm fine with picking up new words, English is obviously is my first language. So, may be it had helped me having English as a first language … again, this is something I can't tell because I'm English

I based on you background

SS10 probably independent thought. I was aware that I was taught differently to general consensus, don't know what it is. Yeah, I was very much aware of that. My Mum will influence me very much to think. You know not to care what are other people thought and generally take a different line. I still sort of have an underdog complex (laughs). I need to even if it's a ridiculous position, if there's you know like two differences of opinion and one of them is like generally widely held one, people believe and another one an underdog one, is less believed, I always support the underdog, I can't help even if it is ridiculous, it's not good in all situations. You know, lots of times it gets me into arguments, but it helps with critical thinking

I how about your learning background? Were you consciously aware that you've been encouraged or to think differently or independently and there's always opportunity for you to apply critical thinking skills in your previous learning?

SS10 yeah, I'd never taught that…I've never been aware of that. I never knew any of that, I didn't go to particularly a good school, but it wasn't a bad school, you know very mediocre. Yeah, there wasn't much of that

I how about the classroom, it was more student centred or teacher centred?

SS10 I don't know what the differences

I that means like the teacher talk more the students talk less or students talk more teacher talk less that means teacher's role is to facilitate…

SS10 teacher talked more, it was teacher centred

I teacher talked more, surprising, yeah?

SS10 yeah, to think it back it was ridiculous!

I do you think this is an isolated case, or do you think it's general…

SS10 no, I think it's general. May be I just not remembering well

I you finish your 6^{th} form, yes?

SS10 yes

I in your 6^{th} Form, how was your student experience, was it very independent, lots of critical thinking, lots of projects which promote critical thinking that kind of things?

SS10 No, we didn't (laughs). No, it was still very much the same. I was very much conscious that we were taught to pass year exams

I so, it's very much exam oriented?

SS10 massively

I umm

SS10 completely… occasionally a teacher would, you know make an effort to do something different. We had like my chemistry teacher she certainly tried to, you know she set a project at one point where you can just research. There's an element of research, it was great, I felt great that's why I get 2 A++, write up a paper about something that you're researching. I think, that's the only thing I remembered we did properly, I think

I how about your primary school?

SS10 it's way back (laughs)

I no, because I've observed students very intelligent at a very young age here, so, I'm just wondering if you've gone through a same process?

SS10 yeah, I like, I think I was the smartest that I ever was when I was in primary school (laughs). That's because I took more interest at early age, sort of interested in Science and my grandma sort of buy for me books about science and it was great, it was really fun

I so, at this stage of your study, have had completed your foundation, how would you conceptualise critical thinking?

SS10 I still think independence of thought, which comes from taking an interest is the key to critical thinking … interest facilitates.

SS10 I still say solving problems, finding solutions in difficult situations and add to that now is coming up with new things, is creating scenarios of your own, solving them, you know. Creating a problem of your own and solving them. Previously, I just thought it's just problem solving now it has changed

I ok, that's it. Thank you very much for participating in my research

SS10 my pleasure

Appendix J **Module Profile**

J.1 Sample Module Profile – University X (EE_X)

Module title	Electricity & Electronics	
Module code (assigned by Banner)	GENG 0004	CRN: 15044
Replacement module (if applicable) (specify module which should be discontinued)	Module code	Module title
Module Lead	Staff number	Name [redacted]
Module Lead profile url:	www	
Other staff associated with module (for Blackboard purposes etc)	Staff number	Name(s) and role e.g. second assessor: [redacted] support tutor
Principal Examiner:	Awaiting new appointment	
Author:	A. [redacted]	
Faculty	FEE	
Academic unit	FEE Foundation Year	
Academic session first offered	2010/11	
Credit Points	ECTS 7.5	15 CATS
Level (4, 5, 6, 7 or 8 in the FHEQ)	Foundation	

Will the module be offered to students from different levels? Please indicate which are applicable (e.g. Level 3 UG module offered to postgraduate students, Level 6 PC module offered to PGR students etc)	No	UG	PC	PR
When will the module be taught (highlight as appropriate)	Semester 0	Semester 1x	Semester 2x	Split module – give dates
Contact hours – *see also appendix 1* **Teaching Hours:** includes lectures, seminars tutorials, project supervisions, demonstration sessions, practical classes and workshops, supervised time in studios / workshops / laboratories, fieldwork, external visits, work based learning. **Independent Study Hours:** includes preparation for scheduled sessions, follow-up work, wider reading or practice, completion of assessment task, revision etc. **Placements Hours:** includes both year abroad, and study defined as 'learning away from the institution that is neither a year abroad nor work based learning and any learning, other than year abroad and work-based learning, that takes place through an organised work opportunity, Teaching placements in medical and health science courses should be treated as placements.	Teaching 72	Placement	Independent study 78	Total 150

Module overview

This module offers an introduction to the scientific principles and methods of electricity and electronics.

Aims and learning outcomes

Aims

- To introduce the scientific principles relevant to electric circuits, and electronic devices
- To introduce the ideas of simple mathematical modelling as applied in electric circuits and electronic devices.

Learning Outcomes

Knowledge and understanding

Having successfully completed the module, you will be able to demonstrate knowledge and understanding of:

A 1. The components of and laws governing dc circuit theory
A 2. The components of and laws governing ac circuit theory.
A 3. The theory of logic circuits and electronic devices

Intellectual skills
Having successfully completed the module, you will be able to:
B 1. Solve simple problems in basic electrical circuit theory.
B 2. Analyse and predict the behaviour of simple logic circuits and electronic devices

General transferable skills
Having successfully completed the module, you will be able to:
C 1. Manage your own learning
C 2. Apply mathematical methods to solve problems
C 3. Apply problem solving techniques to familiar and unfamiliar problems

Summary of syllabus content

TOPIC	RANGE	NOTES
Circuit Theory	Electric current, potential difference, EMF's, resistors, ohms law, power	
	Circuits with one EMF - Kirchhoff's laws, resistors in series and parallel, potential dividers, internal resistance of batteries	
	Measuring current and potential difference – moving coil meters, shunts and multipliers; digital voltmeters and ammeters.	
	Measuring resistance a) by measuring V and I, and b) with a Wheatstone Bridge	
	Multi-loop networks with more than one EMF – branch and loop currents, generating and solving simultaneous equations by applying Kirchhoff's voltage law. Superposition.	
	Capacitors as circuit elements, energy stored in a capacitor, series and parallel connection.	Basic construction and electrical properties of capacitors only at this stage
	Inductors as circuit elements – basic construction and electrical properties, energy stored in an inductor.	Energy stored in an inductor stated without proof.

	Transient response (Charge and discharge) of capacitors. Step and pulse response of C-R circuits	General solution stated without proof
	Transient response of R-L.	Stated without proof
	Kirchhoff's laws applied to Bridge circuits	
	Circuit simplification by utilising Thevenin's theorem.	
Electronics	• Introduction– analogue and digital electronic systems	
Digital Electronics	Examples of digital electronics (switching and control systems, computers, digital signal processing)	
	Combinational logic circuits –one and two input gates, Boolean algebra,	
	Analysis and design of combinational logic circuits, simplification using Karnaugh maps. Circuits with NAND gates only.	
	Sequential logic circuits – flip-flops, counters, shift registers.	
Analogue Electronics	Properties of operational amplifiers	
	Op-amps as comparators – sine to square converter, generation of variable width pulses from a triangle waveform	
	Op-amps with negative feedback – inverting and non-inverting amplifiers, voltage follower, inverting summing amplifier, difference amplifier, differentiator and integrator	Ideal behaviour only
AC Circuit Theory	AC voltage sources, amplitude and phase of voltage across R L and C driven by an AC current source. RMS values.	
	AC networks – phasors and their application (high and low pass filters).	
Electrical Conduction	Microscopic model of electrical conduction – drift velocity, current density, resistivity. The temperature coefficient of resistance.	
Discrete Devices	Diodes and Transistors – diode rectifier, zener diode, the transistor amplifier, the transistor as a switch	Qualitative treatment only
Measurement Devices	Measurement transducers – thermocouples, thermisters, photodiodes, photomultipliers, CCDs	Qualitative treatment only

Summary of teaching and learning methods

Learning activities include

- Individual work on examples, supported by tutorial/workshop sessions/e-learning
- Elements of the coursework module GENG0015 may support your learning in this module.

Teaching methods include

- Lectures, supported by example sheets.
- Tutorials/Workshops/Podcast videos/Online questions
- Printed notes available through Blackboard and/or through your module lecturer.

Summary of assessment and Feedback methods

Assessment method	Number	% contribution to final mark
2 hour unseen written exam	1	95
Tests	5	5

- Individual feedback during lectures or tutorials/workshops.
- Feedback from tests/online problems.

Referral Policy: 95% exam, with 5% test marks carried forward from work produced during academic year.

This module may be taken as an internal or an external repeat. External repeat students will have marks carried forward from the previous year for tests (5%), and therefore exam will contribute 95% of total assessment.

Resources

Core Text

Basic Electronics for Scientists and Engineers, Dennis L Eggleston, Cambridge University Press, ISBN 978-052115430-7

Background Texts

Electrical & Electronic engineering Principles, Morris, Prentice Hall, 1994, ISBN 0582098157

Electronics for today and tomorrow, Duncan, 2nd Edition, John, Murray, 1997, ISBN 0719574137

Mastering Electronics, Watson,4th Edition, Palgrave, 1996, ISBN 0333669703

Any A level physics text e.g. A Level Physics, Muncaster, Nelson Thornes, 4th edition, 1993, ISBN 0748715843, Hartley Library Classification QC 21 MUN

Health and safety

No separate risk assessment required.

J.2 Sample Module Profile – University Y (PROJ_Y)

CET007 PROJECT

Scheme Undergraduate

Department Comp. Eng. & Tech (D)

Level Level 0

Tutor [redacted]

Credits 20

Module Board Computing

Description

TITLE: PROJECT

CODE: CET007

CREDITS: 20

LEVEL: Level 0

FACULTY: FAS

MODULE BOARD: Level zero

PRE-REQUISITES: None

CO-REQUISITES: None

LEARNING HOURS: 200 Hours

LEARNING OUTCOMES

Upon successful completion of this module, students will have demonstrated

Knowledge

K1. Deeper knowledge of chosen topic;

K2. Research techniques;

K3. Project management;

Skills

S1. Take responsibility for own learning;

S2. Apply basic project management skills;

S3. Carry out research, including library research, interviews, assimilation and presentation of data;

S4. Present results, comment upon them, and draw conclusions in the form of a written report and in a formal oral presentation;

CONTENT SYNOPSIS

Permits students to develop and extend a field of engineering/computing which is of personal interest. Students will draw together the other modules of the programme and extend the skills already developed in those modules.

AMPLIFIED CONTENT

A major piece of individual work relating to computing, resulting in an oral presentation and an appropriate piece of practical work and a written element describing the project, its development and findings. Projects will vary depending on the interests of the student.

TEACHING AND LEARNING METHODS:

Scheduled activities Independent study Placement Total hours

Hours Detail Hours Detail Hours Detail

24 Lectures 152 Self Study

24 Tutorials

Total 200

ASSESSMENT METHODS

(Please ensure that the sequence numbering of the assessments is in the correct chronological order for the module, as this may affect funding.)

Required For KIS return to HESA

Seq. Element % of module assessment weighting Summary Pass Mark LO Written exam ? central timetable

Appendix J

(% of the element) Written exam local timetable

(% of the element) Coursework

(% of the element) Practical

(% of the element)

% Type % Type % Type % Type

001 Coursework 100 * K1

K2

K3

S1

S2

S3

S4 80%

Individual assignment 20%

Presentation

* only populate if there is an approved programme specific regulation OR if the assessment is pass/fail

(If the Pass Mark differs from the university regulations there must be a related programme specific regulation approved.)

Assessment 001: practical element and written report and oral presentation that assesses learning outcomes K1,K2,K3, S1,S2, S3 and S4.

INDICATIVE READING LIST (NB: New modules must have an extended reading list)

Crème, P. and Lea, M. R. (2003) Writing at University: a guide for students, 2nd Edition. Oxford University Press.

Peck, J. and Coyle, M. (1999) The Student's Guide to Writing: Grammar, Punctuation and Spelling. Palgrave MacMillan.

Reynolds, G. (2011). Presentation Zen: Simple Ideas on Presentation Design and Delivery, New Riders Press.

Brown, M. (2002) project Management in a Week, 3rd edition. ISBN-10: 0340849371

PROGRAMMES USING THIS MODULE AS CORE/OPTION:

(a) BEng(Hons) Automotive Engineering (Level zero)

(b) BEng(Hons) Electronic and Electrical Engineering (Level zero)

(c) BEng(Hons) Mechanical Engineering (Level zero)

(d) BSc(Hons) Computing (Level zero)

Is the programme delivered On Campus or Off campus (please delete, as appropriate):

On campus

College(s):

Work based learning: No

Professional Accreditation: No

(If yes, by whom and what conditions if any are specific to the module?)

MODULE LEADER [redacted]

LEAD DELIVERER [redacted]

JACS Code: H100

Assessments

CW FINAL: Coursework (100%)

Availability

A: Semester 3 2013/4 [redacted]

A: Semester 3 2014/5 [redacted]