UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF MECHANICAL, INDUSTRIAL AND AERONAUTICAL ENGINEERING

Faculty of Mechanical, Industrial and Aeronautical Engineering

School of Industrial Engineering

An analysis of the 4th year "Systems Management and Integration" course, using individual reflections on working in multidisciplinary groups

Michele Pentz (0108888V)

Research Report

Supervisor: Ms Bernadette Sunjka

DECLARATION

I, Michele Maria Pentz, declare that this research report is my own, unaided work. It is being re-submitted for internal re-examination for the degree of Master of Science in Industrial Engineering to the University of the Witwatersrand.

It contains no section copied in whole or in part from any other source unless explicitly identified in quotation marks and with detailed, complete and accurate referencing. It has not been submitted before for any degree or examination to any other University.

……………………………………..   25 /01/2018 ………………………

Michele Maria Pentz   **Date**

ABSTRACT

It is a requirement of the Engineering Council of South Africa (ECSA) that all tertiary education institutions ascertain whether their current courses meet the ECSA Exit Level Outcomes (ELO), as identified by the institution themselves. The course project for MECN4020 – Systems Engineering and Management – at the University of the Witwatersrand is required to meet the requirement of the ECSA ELO 8, as prescribed. Students are instructed to reflect on the experience.

Qualitative research is used to both induct emergent themes from the student reflections, as well as deduct, whether the ECSA ELO 8 requirements are met by the project.

Emergent themes from inductive analysis result in emergent themes, which are then compared to the pilot study conducted. Deductive analysis identifies the inference that may be placed on the student population, so that the ECSA ELO 8 requirements are identified as met or not met.

ECSA ELO 8 requirements that are considered to be met by the group project for MECN4020 are “The Candidate Makes Individual Contributions”, “The Candidate Enhances the Work of Fellow Team Members”, “The Candidate Benefits from the Support of Team Members”, “The Candidate Communicates Effectively With Team Members”, “The Candidate Acquires a Working Knowledge of a Co-Workers Discipline”, “The Candidate Communicates Across a Disciplinary Boundary” and “The Candidate Uses a Systems Approach”.

Emergent themes and extant literature as used to develop recommendations, so that the MECN4020 project may meet the ECSA ELO 8 requirement. Suggestions for improvement are given using a framework consistent with the design of multidisciplinary education design.

DEDICATION

To Mike Pentz – You will be forever missed

To Amanda Pentz – You will be forever loved

To Dominique Pentz – You will forever be my star

ACKNOWLEDGEMENTS

First and foremost, thanks are given to my supervisor, Ms Bernadette Sunjka, for both the inspiration, support and laughter provided. Her patience and warm guidance have assisted me greatly, with her professional demeanour a constant reminder of my own aspirations.

Secondly, thanks are given to my closest family and friends, with their constant support and love that is a constant. The encouragement, friendship and guidance have bolstered my confidence immensely, and I will forever be grateful that I have a wonderful support system.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF SYMBOLS

For sample size:

$\underline{n}_o$ is the required sample size,

t is the a priori α- value of 0.05,

p is the proportionate variable equal to 0.5,

q is the level of acceptable error set to 5%, and

d is the acceptable margin of error for proportion estimation set to 0.05

For Inference:

$\hat{p}$ is the sample proportion

p is the population proportion

n is the sample size

N is the population size

Hypothesis Testing

α is the level of acceptable significance set to 0.05

z *is* score is a test of statistical significance that helps you decide whether or not to reject the null hypothesis .

p-value is the probability that you have falsely rejected the null hypothesis.

LIST OF ABBREVIATIONS

Abbreviation	Explanation
CPSU	California Polytech State University
CPM	Critical Path Method
ECSA	Engineering Council of South Africa
ECSA ELO 8	Engineering Council of South Africa's Exit Level Outcomes 8 requirements
EI	Electrical and Information
EPA	Engineering Profession Act
INCOSE	International Council of Systems Engineering
JIT	Just in Time
MIA	Mechanical, Industrial and Aeronautical
MECN 4020	"Systems Engineering and Management" Course
MRP	Materials Resource Planning
NIH	National Institute of Health
PERT	Project Evaluation and Review Technique
PRINCE	Projects In Controlled Environments
PMBoK	Project Management Book of Knowledge
SE	Systems Engineering

TCA	Thematic Content Analysis
TPR	Transforming, Performing, Reforming
WITS	University of the Witwatersrand

DEFINITION OF TERMS

Term	Definition
cross-disciplinary	As for *interdisciplinary*.
curriculum (ECSA definition)	“the definition of how a programme is to be executed, including the purpose, the learning, the outcomes or learning objectives, set of compulsory and elective courses, content to support achieving the outcomes, learning activities, methods and media for teaching/training and learning, assessment plan, and a plan for evaluating the quality and effectiveness of delivery” (ECSA, 2003).
discipline [engineering]	“a major subdivision of engineering such as the traditional fields of Chemical, Civil, or Electrical Engineering, or a *cross disciplinary* field of comparable breadth” (ECSA, 2003).
Classification	“Classifications provide a way to record descriptive information about the sources, nodes and relationships in your project” (NVivo, 2013d).
classification, node	“Use node classifications to provide demographic details about the people, places or other 'cases' in your project” (NVivo, 2014).
classification, source	“Use source classifications to store bibliographical information about your sources” (NVivo, 2013g).
classification, relationship type	“Relationship Types are a special type of classification—they let you describe the nature of the relationship” (NVivo, 2013f).
cluster analysis	“Cluster analysis is an exploratory technique that you can use to visualize patterns in your project by grouping sources or nodes that share similar words, similar attribute values, or are coded similarly by nodes. Cluster analysis diagrams provide a graphical representation of sources or nodes to make it easy to see similarities and differences. Sources or nodes in the cluster

	analysis diagram that appear close together are more similar than those that are far apart"(NVivo, 2013e).
Coding	"'Coding' your sources is a way of gathering all the references to a specific topic, theme, person or other entity. You can code all types of sources and bring the references together in a single 'node'" (NVivo, 2013a).
Engineering	"Engineering is the practice of science, engineering science and technology concerned with the solution of problems of economic importance and those essential to the progress of society. Solutions are reliant on basic scientific, mathematical and engineering knowledge. Solutions rely on analysis and synthesis, underpinned by sound techno-economic analysis. Solutions must take into account the needs of society, sustainability and the protection of the physical environment. Engineering work requires management and communication, and must be conducted ethically and within the bounds of applicable legislation. Engineering work is essential to both economic activity and to national development. Engineering work, while offering such benefits also involves health, safety, environmental, economic and sustainability risks that must be managed. Effective, safe and sustainable engineering work is founded on the competence and integrity of engineering professionals" (Engineering Council of South Africa, 2003b).
engineering, aeronautical	"The aeronautical engineer is involved in the design, development and modification of the components and systems of all types of flight vehicles - including fixed wing aircraft, helicopters, sail planes, airships and missiles" (University of the Witwatersrand, 2009).
engineering, electrical	"Electrical Engineers apply the principles of electricity and magnetism to the design of systems and devices relating to electronic hardware, energy transmission, and power utilisation.

	They also oversee the construction and maintenance of these systems" (University of the Witwatersrand, 2012).
engineering, industrial	"Industrial engineering (also referred to as business process engineering) studies the systems, processes, technology and people which make up organisations" (University of the Witwatersrand, 2013a).
engineering, information	"Information Engineers are responsible for developing and maintaining high level systems in which computer software applications, networking and information processing are the essential components "(University of the Witwatersrand, 2012).
engineering, mechanical	"Mechanical Engineering is one of the broadest and most versatile of the engineering professions. The Mechanical Engineer applies scientific principles to the design, development, construction, installation, operation and maintenance of, amongst others, energy production and harnessing equipment, machines and systems in all areas of industry and society" (University of the Witwatersrand, 2013b).
Entropy	A measure to assure statistical significance of results, which provides a measure of "goodness" for un-nested clusters or for the clusters at one level of a hierarchical clustering for external quality measures (reliability)
interdisciplinary	The context of use, at least somewhat integrative, of tools, techniques and methods of more than one [engineering] discipline. *Cross-disciplinary* is taken to have identical meaning.

in-vivo	Context that is taken directly out of a source or student reflection (verbatim), e.g. Wording that participants use in the interview (Khandkar, 2009)
matrix coding	“Matrix coding queries enable you to cross-tabulate how content is coded… You can use Matrix coding queries to ask a wide range of questions about patterns in the data and gain access to the content that shows those patterns… The resulting node matrix can be saved in your project as a query result or with your nodes in the Node Matrices folder.” (NVivo, 2013h)
MRP	“MRP is a set of techniques that uses bill of material data, inventory data, and the master production schedule to calculate requirements for materials. It makes recommendations to reorder materials.” (Dictionary.com, 1999)
multidisciplinary	A context of serial or parallel, but essentially not integrative, use of tools, techniques and methods of more than one [engineering] discipline.
Multilinearity / singularity	“Multicollinearity is a condition which the independent variables are very highly correlated (.90 or greater) and singularity is when the independent variables are perfectly correlated and one independent variable is a combination of one or more of the other independent variables” (Accounting Department, 2013).
Node	“A node is a collection of references about a specific theme, place, person or other area of interest. You gather the references by 'coding' sources such as interviews, focus groups, articles or survey results” (NVivo, 2013b).

Proctor	"Proctors are responsible for upholding the standards and guidelines, reading exam instructions to the student verbatim, monitoring the examinee, return materials accordingly and record & report any suspected cheating incidents and making sure that the exam is provided in the way it was intended by the instructor" (Utah State University, 2014).
relationship type	"A relationship is a special type of node that defines the connection between two project items. You can create relationships in your project and then gather evidence about the relationship from your source material." (NVivo, 2013b)
School, MIA	School of Mechanical, Industrial and Aeronautical Engineering.
School, EI	School of Electrical and Information Engineering.
source	"…'sources' is the collective term for your research materials—anything from 'primary' materials such as documents, videos or survey results, to memos that record your ideas and insights." (NVivo, 2013c)
sub-system	"A subsystem is seen as a partial collection of the elements of the system in which all the original relations between these elements remain unaltered" (Ludwig, 2002).
system [engineering system]	"**2.** A set of devices (e.g. pulleys) functioning together" (*Concise Oxford Dictionary*, 1990). "**7.** ENGINEERING assembly of components: an assembly of mechanical or electronic components that function together as a unit." (*Microsoft® Encarta® Dictionary*, 2005).
the University	University of the Witwatersrand, Johannesburg, South Africa.
trans-disciplinary	A context of "integrated use of the tools, techniques and methods from various [engineering] disciplines" (Bailey-McEwan, 2009)
word frequency	"You can use Word Frequency queries to list the most frequently occurring words or concepts in your sources… You can select the source content you want to search, by selecting sources, nodes, sets, folders or search folders. You can choose to search only in

	the textual content of your sources, in the annotations or both." (NVivo, 2013i)

1 INTRODUCTION

1.1 Background to the Research

The School of Mechanical, Industrial and Aeronautical (MIA) Engineering at the University of the Witwatersrand introduced a fourth year course into their curriculum, which teaches Systems Management Principles at an Undergraduate Level. It is used to introduce the basic principles of systems management, so that students may become familiar with practices and methodologies such as project management, production and operations management, general management principles, systems thinking principles, multidisciplinary groups and safety and the environment (Sunjka 2011a; Sunjka 2012; Sunjka 2013). The course is used to assess Exit Level Outcome (ELO) 8 as specified by the Engineering Counsel of South Africa (ECSA)

ECSA defines the standard for accredited Bachelor of Engineering-type programmes in terms of programme design criteria, a knowledge profile and a set of exit level outcomes. Ten exit level outcomes are specified that be demonstrated in a university-based, simulated workplace context (Engineering Council of South Africa, 2003c). Competencies stated generically may be assessed in various engineering disciplinary or cross-disciplinary contexts. This research specifically addresses the implementation and evaluation of ELO 8 in the MIA 4th year course.

ELO 8 requires that the candidate (4th year undergraduate student) demonstrates competence to work effectively as an individual, in teams and in multidisciplinary environments. It elaborates on these requirements by stating the following (Engineering Council of South Africa, 2003c):

1. The candidate demonstrates effective individual work by performing the following:

   a) Identifies and focuses on objectives;

   b) Works strategically;

c) Executes tasks effectively

d) Delivers completed work on time

2. The candidate demonstrates effective team work by the following:

   a) Makes individual contributions to team activity;

   b) Performs critical functions;

   c) Enhances work of fellow team members;

   d) Benefits from the support of team members;

   e) Communicates effectively with team members;

   f) Delivers completed work on time.

3. The candidate demonstrates multidisciplinary work by the following:

   a) Acquires a working knowledge of a co-workers' discipline;

   b) Uses a systems approach;

   c) Communicates across disciplinary boundaries.

In the School of MIA, ELO 8 is assessed in MECN4020 through a group project. The project requires that students from each discipline (Mechanical, Electrical, Industrial, Information and Aeronautical) form a group. There are rules in place so that each group is multi-disciplinary in nature:

- 1 Aeronautical student only;
- 1 Industrial student only;
- 1 Information student only;
- Ratio of Mechanical to Electrical at 2:3 to be split into the groups thereafter.

The students are given a project, whereby a group of 5 students from different engineering schools are required to execute a case study analysis, which requires the students to conduct reading and research on the case study (mapping and explanation of the systems including the Systems Management process, methodology and life-cycle for the product). Students are assigned case studies, which differ from year to year.

The course started implementing ELO 8 in 2012, although the group projects had been running since the inception of the course in 2010. The project is therefore designed to meet the requirements outlined in ELO 8 (Appendix A).

The course differed throughout year 2011, 2012 and 2013 (Appendix B). The differences were as follows:

Table 1-1 – Comparison of Variables by Year

Year	2011	2012	2013
Hand-Out Date	21-Feb-11	11-Feb-12	11-Feb-13
Due Date	06-Jun-11	10-May-12	10-May-13
Group Project Weighting	50%	60%	65%
Number of Case Studies	12	2	2
Weighting of Reflection	10%	10%	10%

1.2 Importance of the Study

Multidisciplinary disciplinary programs may be defined as a group of individuals who work collectively on a project, but do not focus on their field of specialization, but rather collaborate on the entire project through the lens of their particular specialization (Braun *et al.*, 2007a). Many tertiary education bodies focus on multidisciplinary studies and may combine disciplines that are loosely related or not related at all, allowing for the amalgamation to create a new approach that then challenges the traditional ways that have otherwise been used. In fact, an interdisciplinary team may allow for solutions that would not have otherwise been considered (Braun *et al.*, 2007a).

When collaboration or research results in new solutions to problems, much information is given back to the various disciplines involved. It is therefore very dependent on both specialists as well as multi-disciplinarians. According to NIH, the most critical technological and socio-technological challenges facing the world today require multidisciplinary approaches to resolve (Maura Borrego, 2010a).

A study by Maura Borrego and Lynita K. Newswander (Maura Borrego, 2010a) found that applying the lens of multidisciplinary studies (humanities) to science and engineering provides important depth and focus to engineering and science multidisciplinary learning outcomes, particularly in detailing integration processes. The authors further suggested that they were able to identify five categories of learning outcomes for multidisciplinary graduate education: disciplinary grounding, integration, teamwork, communication, and critical awareness.

1.3 Research Problem

While the course has been operating for three years, there has not yet been an evaluation of the course to ascertain whether the project component ensures that students meet the requirements of the ELO 8. A means to potentially evaluate the course in terms of the requirements for ELO 8 is through feedback from the students. ECSA requires that students provide confidential feedback of their experience in a multidisciplinary project. The students were, thus, asked to write a reflection, which is a subjective narrative that includes the personal perception of a particular experience.

The brief given to the students provided a guideline for the reflections: "As a group and as individuals, reflect on the experience of working in an interdisciplinary group i.e. how did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc" (Sunjka 2011; Sunjka 2012b; Sunjka 2013). This research proposes that an analysis of these reflections will assist in evaluating whether the MECN4020 projects ensure that students meet the requirements of ELO 8.

1.4 Critical Research Question

The critical research question is "Does the group project for MECN4020 meet the ECSA ELO 8?"

1.5 Research Objectives

The overall objective of this research is to evaluate whether the group project for MECN4020 effectively ensures that students meet the requirements of ELO 8 (Coombs, 2013).

Specific objectives of this research are to:

1. Identify emergent themes within the reflections of the students
2. Assess the relationships between emergent themes
3. Assess whether the ELO 8 requirements are met
4. Assess whether the requirements are met using inferential statistics.

1.6 Method

These objectives will be achieved the Thematic Context Analysis (TCA) using NVivo Software to identify and compare themes to the ELO 8 requirements. Inferential statistics and hypothesis testing are used to understand whether significant differences can be detected within defined subgroups. This would include the differences in the following areas:

1. Year of the project
2. Case Study given
3. Branch of engineering

1.7 Limitations and Assumptions

The research is conducted within the following framework:

- The research is based on three years' worth of qualitative data as given by the students.
- This study assumes that any data given by students is truthful and not biased although it is being handed in for marking to a lecturer.
- This study is limited to students that are registered for the course of Systems Engineering from the Faculty of Engineering at the University of the Witwatersrand.
- The project commenced in July 2011 and will run until June 2013.
- The research is limited by availability of resources and the information provided by the students registered for the course as stated previously.
- The feedback from repeating students will be excluded as it is not their initial contact with systems engineering and a multidisciplinary environment.
- The ELO 8 of the student for Individual working will be excluded as it is there is no method of determining the outcome from the students' personal reflections

1.8 Organisation of the Report

Chapter 1 (Introduction) outlines the background to the research, building up to the purpose of the research. The objectives of the research are discussed so that the overall research setting for the is study is presented

Chapter 2 (Literature Review) includes describes the outcomes level as devised by ECSA, the differences between cross-disciplinary systems approach, and the various aspects associated with previous work identified by the University of the

Witwatersrand, other tertiary institutions, critique identified with each, and the transference of knowledge across disciplinary boundaries concerned with the semantics and paradigm shifts associated with each transference, as well as the framework suggested for interdisciplinary studies in education.

Chapter 3 (Proposed Research Method) identifies the qualitative approaches that may be used in analysis of reflections, selects a method based on merits, and describes the process of analysis. Deductive analysis is discussed, with statistical parameters and tests identified and selected. It further explores the requirements of reliability, validity, generalisation and credibility of the research being conducted.

Chapter 4 (Analysis and Results) uses inductive and deductive analysis. Inductive analysis allows for the exploration of emergent themes of each discipline and school of engineering. It allows the emergences of sub-themes regarding the above, allowing for a better understanding into all deductive analysis. Deductive Methods and Results is used to explore Engineering Council Outcomes Level 8, and creates a framework of solutions to extend on the outcomes based on any extant knowledge outlined in Chapter 2, as well as conductive idealisms that were considered from previous learning.

Chapter 5 (Discussion and Findings) is the of the project, and indicates several relationship dependencies that may in turn be dependent on findings from within the Fourth Year Engineering Management and Engineering scope of the project confines, allowing for the cross reference of Literature survey to bolster what has been found.

Chapter 6 (Conclusions and Recommendations) relates to findings found with the study that alludes to any research completed, and summarises the findings, whilst stating the hypotheses, and identifying requirements.

2 LITERATURE REVIEW

The purpose of this literature review is to explore the concepts related to the key areas of competency required by ELO 8. These include multidisciplinary work, team/group work, and systems thinking in educating under-graduates.

In light of the research question, an introduction to the Engineering Council of ECSA is provided, and the prior cross-disciplinary work conducted by the students will be discussed in terms of the experience of the educator and the outcomes of the students. The Systems Engineering and Management course will be discussed, as well as a pilot study conducted by Sunjka. Finally, processing of information across boundaries as well as group formation dynamics will be addressed, as they are seen to be pivotal in both multidisciplinary and interdisciplinary work.

Its range statement requires that multidisciplinary tasks require co-operation across at least one disciplinary boundary. Co-operating disciplines may be engineering disciplines with different fundamental bases other than that of the programme. This may be extended to other studies, outside of the engineering field (Engineering Council of South Africa, 2003c).

2.1 Multidisciplinary, Interdisciplinary and Transdisciplinary Working

Although all three terms are exchanged intermittently by many, there are distinct differences between the three forms of discipline. The interdisciplinary approach is uniquely different from a multidisciplinary approach, in that the teaching of topics from more than one discipline in parallel to the other is completed. It also differs from the cross- disciplinary approach, where one discipline is crossed with the subject matter of another (Jones, 2010). Reference from a health care journal has been used as an additional resource for the below definition, so that the boundaries of each are clearly outlined.

A simplified comparison of the disciplines is outlined in the below table (Klein, 2008):

Table 2-1: Comparison of Multidisciplinary, Interdisciplinary and Transdisciplinary Work (Klein, 2008)

Evaluation Principles	Interdisciplinary Work	Multidisciplinary Work	Transdisciplinary Work
Variability of Goals	A Single Goal	No Single Goal	No Single Goal
Variability of Criteria and Indicators	Identify With Own Discipline	Ability to Work In Different Discipline	Recognition Within and Outside Own Discipline
Leveraging of Integration	General Systems Theory	General Systems Theory	Delphi Method
Interactions of social and cognitive factors in collaboration	Need to calibrate separate standards while managing tensions through compromise and negotiation.	Individuals first address questions by themselves, and then arrive at a common plan together	Priori Approach
Management, Leadership and Coaching	Group is pushed quickly toward integration, the crucial activities of building rapport and exploring ways to understand how each discipline approaches a research question short-changed	Repeating the process ensures that reviewers gain the necessary competence and a communication base over time, facilitated by the empowerment of applicants and the enforced interdisciplinary learning of reviewers	External boundaries must be spanned, and internal linkages and information flows brokered across different disciplinary cultures, status hierarchies, and organizational structures.

Evaluation Principles	Interdisciplinary Work	Multidisciplinary Work	Transdisciplinary Work
Iteration in a Comprehensive and Transparent System	Training, collaboration, and integration only	Basic activities lead to new and improved methods, science, and models that are tested and lead to publications.	The central insight is that the mobility of participants and interaction and communication patterns furnish a heuristic for identifying differences in social domains or contexts for knowledge production. Transparency requires that both evaluators and participants are informed of criteria from the outset and, ideally, are involved in defining them
Effectiveness and Impact	Long-term impacts could not be predicted or measured fully at the outset	Long term impacts identified as risks	The inclusion of unpredictable long-term impacts, returns on investment/ value-added

Ambiguity on the term multidisciplinary is shown when comparing the above table to the ECSA Exit Level Outcomes. However, during analysis, the definition of multidisciplinary will be used as given by ECSA. The terminology used by the student will not be used as a method of identification.

2.2 Multidisciplinary/Interdisciplinary Study in Tertiary Education Institutions

Multidisciplinary programs may be defined as a group of individuals who work collectively on a project, but do not focus on their field of specialization, but rather collaborate on the entire project through the lens of their particular specialization (Braun *et al.,* 2007a). Multidisciplinary programs therefore differ from other programs in that the specialised individual does not concentrate on their area of expertise.

Many tertiary education bodies focus on multidisciplinary studies and may combine disciplines that are loosely related or not related at all, allowing for the amalgamation to create a new approach that then challenges the traditional ways that have otherwise been used. In fact, a multidisciplinary team may allow for solutions that would not have otherwise been considered (Braun *et al.*, 2007a). When collaboration or research results in new solutions to problems, much information is given back to the various disciplines involved. It is therefore very dependent on both specialists as well as multi-disciplinarians. The most critical technological and socio-technological challenges facing the world today require multidisciplinary approaches to resolve (Maura Borrego, 2010a).

Advocates for Multidisciplinary study

A study (Maura Borrego, 2010a) found that applying the lens of multidisciplinary studies (humanities) to science and engineering provides important depth and focus to engineering and science multidisciplinary learning outcomes, particularly in detailing integration processes. The authors further suggested that they were able to identify five categories of learning outcomes for multidisciplinary graduate education: disciplinary grounding, integration, teamwork, communication, and critical awareness (Maura Borrego, 2010b).

2.2.1 BASE-LINE RESEARCH FOR MULTI-DISCIPLINARY TEACHING

OVERVIEW

An assessment of interdisciplinary studies was conducted by the California Polytechnic State University (CPSU) for a capstone course in environmental studies. It required students to analyse global environmental issues, resources and human activities using a prescribed systems approach, whereby scientific, economic, political, social and ethical objectives were require (Braun *et al.*, 2007b).

The project requirement of the course required students to select a global environment issue and local manifestation thereof, and thereafter to analyse relevant resources, develop technical recommendations, perform economic analysis and develop political recommendations for the implementation of the solution. (Braun *et al.*, 2007b)

GUIDELINES TO STUDENTS

The approach taken by the CPSU is similar to that of the fourth year Systems Engineering and Management course in that both require unique contributions from each student, and allow each student to learn from their team. Caveats given to the students of CPSU (Palmer, 2006) overlap strongly with the guidelines given by Wits University and ECSA, as well as systems management and are clustered below (Palmer, 2006):

1. Communicate across disciplinary boundaries

"Thou shalt refer to thy neighbour's ideas" "Thou shalt let thy students speak"

"Thou shalt model debate with thy neighbour"

"Thou shalt ask open questions"

"Thou shalt let thy students speak"

2. Acquire a working knowledge of a team members discipline

"Thou shalt attend thy neighbour's lectures"

3. Effective communication

"Thou shalt plan everything with thy neighbour"

"Ye shalt apply common grading standards"

"Thou shalt attend all staff meetings"

4. Make individual contributions

"Thou shalt have something to say, even when thou art not in charge"

Course Deliverables

The approach taken by both universities are also similar in that the project is broken into phases, each involving a written assignment. The group assignment is preceded by individual assignments, allowing the students to identify with the case using their own working knowledge, and thereafter sharing their insights with their team members, so that a group solution is created. Both universities focus on using a specific project approach as the framework for the students' reference (CPSU uses PRINCE, whilst Wits University uses PMBoK), deliverables including a final written report, presentation, Gantt chart and cost cycle analysis (Braun *et al.*, 2007b) (Sunjka 2011) (Sunjka 2012) (Sunjka, 2013).

Assessment of Student Learning

The assessment of the student learning was measured using a survey, which rated their opinions about their ability to perform each of the course objectives and outcomes. Predefined questions with an assigned pseudo-Likert scale and rubrics (for dichotomous answers) and therefore the analysis was quantitative, in contrast to the research conducted for this dissertation (Braun *et al.*, 2007b).

It was found that the most significant differences displayed by students before and after were those around apply analysis of environmental issues, applying the first law of ecology, explaining the consequences of global warming, and measuring and reducing your ecological footprint (Braun *et al.*, 2007b).

Several areas were identified by the study that suggested that there was no significant difference in the students' perception when comparing pre and post survey results. Interestingly, several areas showed insignificant changes and these include (Braun *et al.*, 2007b):

- Evaluating evidence and information about environmental issues,
- Ethical dimensions of environmental issues,
- Implementing strategies to achieve sustainability,
- Working with others from different backgrounds to pose and evaluate resolutions to complex problems
- Listing ways to decrease ecological footprints

There is an overlap in the concept of many of the ECSA Outcomes Level 8 requirements and some of the questions posed in the study performed by CPSU, and it is therefore envisioned that the research of the reflections of the students' for this dissertation will follow a similar pattern (Palmer, 2006) (Braun *et al.*, 2007b):

- Acquire a working knowledge of a co-workers discipline (Evaluating evidence and information)
- Communicating across a disciplinary boundary (Implementing strategies)
- Using a systems approach (Working with others from different backgrounds to pose and evaluate resolutions to complex problems).
- Ethical dimensions of environmental issues,
- Implementing strategies to achieve sustainability,
- Working with others from different backgrounds to pose and evaluate resolutions to complex problems
- Listing ways to decrease ecological footprints

There is an overlap in the concept of many of the ECSA Outcomes Level 8 requirements and some of the questions posed in the study performed by CPSU, and it is therefore envisioned that the research of the reflections of the students' for this dissertation will follow a similar pattern (Palmer, 2006) (Braun *et al.*, 2007b):

- Acquire a working knowledge of a co-workers discipline (Evaluating evidence and information)
- Communicating across a disciplinary boundary (Implementing strategies)
- Using a systems approach (Working with others from different backgrounds to pose and evaluate resolutions to complex problems).

A keen focus on using a systems approach was found and was deemed the pivotal to success.

2.2.2 PRIOR MULTI-DISCIPLINARY COURSES AT WITS

Students in the School of Mechanical, Aeronautical and Industrial Engineering are introduced to a compulsory form of cross-disciplinary in their third year of study. The subject combines mechanical disciplines with electrical disciplines, and first introduces the third year undergraduate student to the philosophy of mechatronics. The second and final course is completed in fourth year, and builds upon the first course by increasing the focus of advanced modelling and control topics (Bailey-McEwan, 2009).

BRIEF OUTLINE OF MECHATRONICS

The course outline and composition is described by the lecturer as "designing the most synergistic, integrated combination of technologies into a product or system for optimal versatility, performance and cost-effectiveness. Second, it introduces the technologies of the essential sub-systems – the measuring, control and actuating systems – of any mechatronic device, and the main features of the components available for each of these sub-systems. Finally, and just as importantly, its laboratory project is a major team project of designing, building and testing a working model of a full-scale mechatronic device" (Bailey-McEwan, 2009).

PERCEIVED DEFICIENCIES AND REMEDIES

It was perceived that the course did not awaken students to the analogies between electrical and mechanical devices, nor the common fundamental principles governing the behaviour of both. The ‘compartmentalisation’ by students was a concern, and perceived deficiencies were identified as the lack of a design-oriented approach and deficiencies of traditional engineering curricula (Bailey-McEwan, 2009). Furthermore, it was stated that any prior courses purported to creating a fundamental understanding of the electrical branch of engineering was considered it a “tack-on” course. Remedial steps included preparatory work such as laboratory exercises to include programming of micro-controllers, interfacing to sensors and actuators (Bailey-McEwan, 2009).

It was found that the Bernsteinian collection type of educational knowledge was used, rather than an integrated type, where bodies of knowledge of engineering sub-disciplines were uneasily connected only at their boundaries (Bailey-McEwan, 2009). This was deemed as inadequate for the purposes of interdisciplinary demands of engineering practice. The methods of assessing the students mechatronic knowledge was also found to be lacking, thereby allowing students with materially inadequate knowledge to proceed to their final year of study. Recommendations included integrating students’ everyday experiences of the real world, along with acquired knowledge, with formalised subject-matter concepts; to envisage that “experientially rich spontaneous concepts, arising from working experiences in this laboratory project and illuminated by previously acquired knowledge, will move upwards, meet and fuse into downwardly developing subject-matter concepts” (Bailey-McEwan, 2009).

The need to focus on a “systems approach” is verified in this study, as it is in the CPSU study. It aligns with the ELO 8 requirements and will be researched further.

2.3 The “Systems Approach”

2.3.1 UNDERSTANDING THE SYSTEMS APPROACH

The term “systems approach” is used and is defined as a team of cooperating experts in both the technological and non-technological aspects of the system to be analysed (Ramo and St Clair, 1998). Traditional protocol suggests the initiation of the project be the outlining of goals and objectives and concludes with a description of a harmonious, optimum ensemble of the required human and machine components, with a corollary network of flow of information and materials that allow the system to operate in order to meet the goals and objectives outlines (Ramo and St Clair, 1998).

This is a very simplistic view of systems approach, as the approach should also entail:

- The use of assembling and processing techniques for the data,
- The comparison of alternatives by comparing shortcomings and benefits,
- Making compromises and ensuring consensus in solution,
- Introducing creative innovations where the need is indicated (Ramo and St Clair, 1998).

It is "a reasoned and integrated, rather than a fragmentary, look at problems. It seeks to push confusion and hit-or-miss decision-making into the background. It leans heavily on rational, concrete judgements" (Ramo, Simon, St.Clair, 1998).

There are various contradictory views on the relevance or indeed the benefit of the systems approach, and these are often held by persons who do not understand the approach itself, resulting in poor application thereof (Ramo and St Clair, 1998). Consider the aeronautical engineers or electrical engineers who use the systems approach, but do not apply the skill outside of their specialised field. This is an example of systems engineering being utilised in a small context, and fails to highlight the benefits that a systems approach.

In large context, the emphasis in the inclusion of social impacts is pivotal; the exclusion of the human element in solutions around medical care, education, and even traffic control will ultimately result in a piecemeal solution – emotional and chaotic – as these behaviours were not considered in the approach and thus no solution would include them (Ramo and St Clair, 1998). Large context systems approach therefore requires the systems approach to be a "deliberate, skilled effort to utilize experience, talent and conceptual tools, as well as all of the facts and the mechanical aids" (Ramo, Simon, St.Clair, 1998). The approach, if used wisely and with appropriate application, can, at a most minimal level, reduce the inherent chaos that is found in most systems today.

2.3.2 THE "PIECEMEAL" APPROACH

The piecemeal approach may be confused with the systems approach, as both consider the subsystems of the primary system; yet the piecemeal approach delivers a solution that is highly disorganised, with subsystems often superbly engineered, but the combination of subsystems incompatible, compromised and chaotic (Ramo and St Clair, 1998). A piecemeal approach may well then result in a half and half systems approach, whereby the approach taken is done with subsystems in isolation, combined hastily, resulting in orchestrated chaos.

Examples of piecemeal approaches are strewn across the history of mankind, from the air transport system to the medical care fields. The consequences of piecemeal approaches often lead to delays, inefficiencies, slow information transfer, congestion, down-time and reduced effectiveness. Redressing the issue of a piecemeal approach places considerable emphasis on competent system analysis, and the allocation of additional resources, including funding, people, new technologies and of course, time (Ramo and St Clair, 1998).

2.3.3 SYSTEMS APPROACH IN THE ENGINEERING CONTEXT

Systems approach, when used in the engineering context, may be quite problematic. The definition of an engineer is broadly understood as "the application of science and technology to the needs of society" (Ramo and St Clair, 1998). ECSA itself defines the professional activity of engineering as "intellectual and conceptual working using engineering knowledge and engineering competencies to conceive, create, design and implement components, systems, engineering works, products and processes to solve problems of economic or social value" (Engineering Council of South Africa 2003). Most engineers are considered as specialised in their field (Ramo and St Clair, 1998), and do not specialise in any form of training in the social sciences.

A requirement of a sound systems engineering team is to have a compliment of various specialized individuals – government, economists, accountants, politicians – and facilitate the interaction problems among these specialities. The requirement for inter-disciplinarians is highly stressed, as they are considered generalists who can orchestrate the complete contributions and skills of the specialists, thereby creating an integrated and unifying team (Ramo and St Clair, 1998).

In short, and succinctly stated: “As goods and services become more multifunctional, engineering practise is becoming increasingly integrated across traditional engineering disciplines” (Bailey-McEwan, 2009).

2.4 Introduction to Systems Engineering

“Systems Engineering” may be defined as a “collaborative approach to derive, evolve and verify a life-cycle balanced system solution that satisfies customer expectations and meets public acceptability”. (Dickerson and Mavris, 2010). This definition was extrapolated further to encompass the “the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, user and user training for, systems products and processes; the definition and management of the system configuration; the translation of the system definitions into work break down structures; and the development of information for management decision making” (Dickerson and Mavris, 2010).

There are many definitions of Systems Engineering, but essentially, the context is similar: Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to optimal operation (Dickerson and Mavris, 2010) (Karl Arunski, P.E., James Martin, Phil Brown, P.E., Buede, 1999) (Wray, Snoderly and Olson, 1994).

2.4.1 The Need For Systems Engineering

The rapidly changing and dynamic world is increasing reliant and in need of scientific discovery and technological development, as the average individual demands more, demands faster, demands better. The requirement of urban developments, transport systems, health systems, water and sanitation requirements, crime prevention and communication are but a few systems that are required to constantly be improved. (Ramo, Simon, St.Clair, 1998)

When considering the breakthroughs in many disciplines and sectors of science, it becomes apparent that not only have the subsystems within become more complex and integrated, but the social wisdom required for such large developments has not been created to transform the knowledge to its optimal function. A good example is that of the human genome project (Ramo, Simon, St.Clair, 1998)

Great advances have been made in the understanding of the human genome, allowing us insights into significant social concerns such as longevity and predisposition to disease, (Ramo, Simon, St.Clair, 1998) yet somehow the same project, promising such wondrous 'improvements' to our well-being, is now contentious (News24 2013), as allegations of neo-racial research make headlines. Could this not have been avoided had a large systems approach been used, with the design not only encompassing biological knowledge, but the inclusion of social wisdom to put these discoveries to work, rather than be the subject of contention? Myriad examples exist where a small systems approach has been hindered purely because of failure to assume a large systems approach and thereby include socio-economic frameworks (Ramo and St Clair, 1998).

The improvement of these systems is complex, not only due to the complex subsystems, but also the dependencies created in the system. It is therefore a growing phenomenon and requirement in all aspects of our everyday lives, with technological developments themselves ever pushing the envelope for better, faster, smarter and systematic (Bailey-McEwan, 2009).

2.5 Systems Engineering and Management at Wits University

The idealism of Systems Engineering that has been adopted by The School of Mechanical, Industrial and Aeronautical Engineering is an interdisciplinary process that ensures that the customer's needs are satisfied throughout a system's entire life cycle. This process includes understanding customer needs, stating the problem, discovering system requirements, defining performances and cost measures, prescribing tests, validating requirements, conducting design reviews, exploring alternative concepts, sensitivity analysis, function decomposition, system modelling, system design, designing and managing interfaces, system integration, total system test, configuration management, risk management, reliability analysis, total quality management, project management, and documentation" (Bahill and Dean, 2009).

2.5.1 PILOT STUDY BY B. SUNJKA

Feedback given by students was used as a qualitative data set, comprising of 300 word written reflections of 185 students. Thematic Content Analysis (TCA) was used to portray the thematic content of texts by identifying common themes, whereby the researcher grouped and distilled common themes from the texts to give "expression to the communality of voices across participants". The major themes identified were (Sunjka, 2011b):

- Team Dynamics
- Interdisciplinary features
- Time Management
- Student Personal Learning

TEAM DYNAMICS

Expresses the various aspects of how the groups organised themselves and their work and the challenges faced in this organisation. The dynamics of team forming, storming, norming, performing was identified Sub-themes expressed and identified were (Sunjka, 2011c):

- Communication
- Previous acquaintance with team members
- Attitudes, behaviours of group members – mutual respect
- Division and management of work – team roles
- Leadership
- Previous experience of group work
- Cultural, religious, moral issues

- Conflict: origins and management
- Decision-making processes

Interdisciplinary Features

Expresses the personal experience of working with students from other engineering disciplines. Sub-themes expressed and identified were (Sunjka, 2011c):

- Approaches/views/styles of working/problem-solving of other
- Disciplines
- Inter-school vs. in-school
- Professionalism
- Skills – discipline specific eg. Aero, Ind, Mech, Elec
- Interpretation of terminology/technical language
- Creating mutual understanding
- Learning from each other
- Interpretation of the project/case study

Time Management

Expresses the challenges encountered with finding time to work together and track the progress of work. Sub-themes expressed and identified were (Sunjka, 2011c):

- Differing schedules of members
- Scheduling of meetings
- Attendance at meetings
- Alternatives to meetings
- Planning of time
- Frustrations with time management

PERSONAL LEARNING

Expresses the personal learning gained by the student and how the experience relates to the real world. Sub-themes expressed and identified were (Sunjka, 2011c):

- Overall experience – positive or negative
- Personal fears
- “I have learnt …”
- Learning from others
- Learning as related to the Real world

CONCLUSIONS

It was found that the meeting of Course Objectives were positively reflected in that students were introduced SE principles, provided a teamwork and team learning experience and provided inter-disciplinary experience. The overall student opinion was positive, with students stating that they had learnt from peers; felt it was a worthwhile experience and that it allowed them to relate to the real world of work (Sunjka, 2011c).

Certain adaptations were made from these conclusions, and changes in the course and project were made. This included reducing the allocated project to 40% from 50%, discontinuing presentations, allocating time for the students to work on the project, and changing the case study material. Future research suggestions were to investigate the sub-themes in more detail, evaluate differences across teams and relate the findings to extant literature (Sunjka, 2011c).

2.6 Multidisciplinary and the Systems Approach

In theory, there are three levels of communication complexity that exist in the developing of an integrative framework. These are divided into syntactic, semantic and pragmatic (Carlile, 2004).

2.6.1 Syntactic/Information Processing

This approach works well between engineers within the same discipline, as the requirement of this approach to transfer of knowledge is that of the storage and retrieval of knowledge between individuals that are privy to the same lexicons and common knowledge (Carlile, 2004). Syntactic processing therefore occurs when engineers work within the same discipline. As it requires stable conditions to facilitate development, it breaks down when any novelty (uncertainty) occurs. Most interdisciplinary work may be done using syntactic processing, However, the syntactic, or information, processing boundary is not considered suitable for the outcomes required for this study (Carlile, 2004) (Bailey-McEwan, 2009).

2.6.2 Semantic Processing

Semantic processing is considered more complex than syntactic processing due to the introduction of novelty or uncertainty. Novelty may manifest as different requirements, persons, ambiguous or differing terminology, measurement or outcome (Carlile, 2004). The consequences of utilizing this type of processing can differ; the group may create a cross-functional team who share methodologies and problem-solving, or allow a particular individual to act as a translator and enable the flow of knowledge. Semantic processing relies heavily on expressing knowledge explicitly for the success of the project, unlike syntactic processing, where knowledge may be expressed tacitly, as all participants are from the same field. Negotiation and trade-offs are commonplace so that an adequate solution is created, as participants are willing to change and amalgamate the knowledge and interests from their own discipline (Carlile, 2004). This is due to the translating of different ideas and opinions and subsequent exploration of consequences as required by the project, to result in a shared resolution.

Semantic processing occurs within the school of MAI and also within the school of EI, as both schools prescribe that the first and second year syllabus within the same school are the same, with specialization of their discipline occurring in their third and fourth year of study (Bailey-McEwan, 2009). Projects run within the School of MIA, or alternatively, within the School of EI, would therefore be considered as mostly semantic processing, but may also overlap into pragmatic processing, due to the specialization of each discipline in the third and fourth year of study (Carlile, 2004). An example of semantic processing was provided by the Mechatronics projects completed in the third and fourth year of study.

2.6.3 PRAGMATIC PROCESSING

In pragmatic processing, the participants have different interests but the same dependencies. Discipline specific knowledge may need to be transformed so that the effective sharing occurs. Although also reliant on trade-offs and negotiation, pragmatic processing differs from semantic processing in that the knowledge provided by the participant is invested in the project, and the participant is therefore “threatened” due to the hefty novelty of their contribution and lack of understanding by peers (Carlile, 2004). It is a highly volatile trade-off, as the conceptualisation from one discipline may evoke a negative reception from the other, and often end in complete opposition of ideas (Carlile, 2004).

For a successful project, it is imperative for participants to present current knowledge, realise and confirm the consequences of using the current knowledge, and to transform their understanding of the above to the other discipline (Carlile, 2004). Although pragmatic processing occurs more frequently between faculties, rather than disciplines, it may present itself between fourth year students of different disciplines due to their specialization, moreover, those of the Electrical and Information students completing a project that falls within the confines of the School of MIA (Carlile, 2004).

2.7 Systems Engineering Framework for Education

There are many sources that indicate that the current level of “Systems Engineering” used globally is not sufficient (Siddiqui, 2013) (Benson and Newell, 1983) (Bailey-McEwan, 2009). The design of education systems that integrate ‘the systems approach’ and forms of cross-disciplinary are controversial at best, with many educators and education bodies applying several different methodologies to incorporate what they purport to be the best approach.

The System approach is a rational, problem solving method of analyzing the educational process and making it more effective. It is fundamental to understanding *(Siddiqui, 2013)*. The improvement of the quality of education is seen to require a design that is open, organic, pluralistic and complex (Siddiqui, 2013). Several requirements are seen as to ensure that the education institution is successful. The education institution needs to modulate constant change, uncertainty, and ambiguity while maintaining the ability to co-evolve with the environment by changing itself and transforming and the environment (Siddiqui, 2013). Single loop learning, where the student repeats the same method, is to be adjusted to that of double-loop learning, where the student is able to modify his/her methods and understanding in the light of experience. The educational institutions should also allow for, or develop, the capability for self- reference, self-correction, self-direction, self-organization, and self-renewal (Siddiqui, 2013). The educational institution is, therefore, also a system, with the aspects or components, which should include hardware, instructional media and personnel structured into a single unit (Siddiqui, 2013).

'Mastery Learning' and 'Keller´s 'Personalized System of Instruction' is seen as the foundation on which educational institutions should build all their systems-approach and cross-disciplinary work. 'Mastery Learning' identifies that mastery of foundation subjects are necessary for success (Bailey-McEwan, 2009) (Siddiqui, 2013), and that the summative evaluation is be used, whereby a general assessment is used which 'sums up' the total achievement in the course (Siddiqui, 2013). 'Keller´s 'Personalized System of Instruction' places emphasis on self-pace, stress upon the written word, the use of proctors, and using contact time with the student for motivation, rather than pure instruction (Siddiqui, 2013).

Three phases are suggested for the development of a sound systems-approach and cross-disciplinary course or project, and are shown below (Siddiqui, 2013):

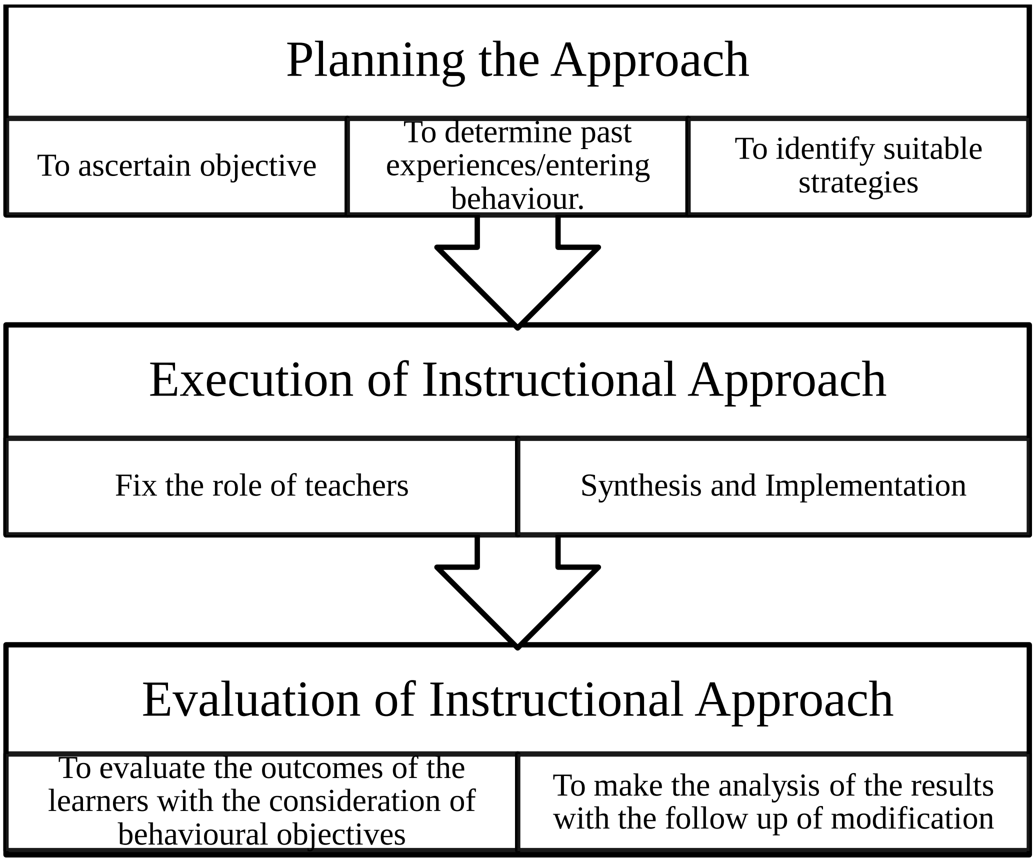


Figure 2-1: Fundamentals or Integrative Teaching

Further debate on the approach hinges on three factors (Nicholson, 1987):

- Only one valid theoretical approach to multidisciplinary studies is needed
- The belief that unanimous agreement in the theory of interdisciplinary studies is a possible or even a desirable goal, and
- Consensus on general principles and methods will provide interdisciplinary studies with a new legitimacy which is presently lacking.

Although there is no agreement on the absolute approach for integrative studies (Nicholson, 1987) (Mansilla, Duraisingh and Question, 2009) (Klein, 2008) (Benson and Newell, 1983) (Benson and Newell, 1983), the above steps are identified as the fundamental requirements, and should be established before any move to cross-disciplinary and/or systems-approach based education is considered (Siddiqui, 2013).

2.8 Considerations from Previous Research

Two other aspects were to be considered along with the systems approach. The areas of concern are noted and are therefore explored.

2.8.1 The Critique of Systems Engineering in Tertiary Education

As with all forms of education, there are several sources that advocate Systems Engineering, whilst others have several concerns about this approach. Although there are many advantages such as expanding student understanding and achievement between all disciplines or enhancing communication skills, disadvantages such as integration confusion and time-consuming curriculum preparation are considered barriers to effective interdisciplinary learning (Jones, 2010).

2.8.2 Group Formation and Communication

Due to the complex nature of interdisciplinary study, consideration of the three levels of communicating across boundaries should be bolstered by an understanding of group dynamics. As interdisciplinary groups are usually created with individuals that are not well known to each other, the developmental sequence to group dynamics should be considered.

The most influential model used is that of Tuckman (Infed, 2010) , who identified four (and subsequently a fifth) stage of developmental sequence; Forming, Storming, Norming, Performing and Adjourning.

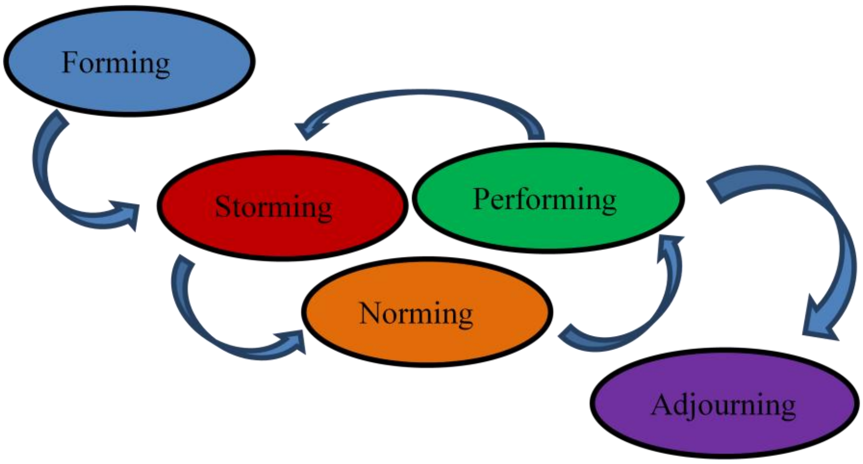


Figure 2-2: Group Development Phases

The five stages may be explained as follows:

FORMING:

Individuals initially concern themselves with orientation, primarily accomplished through testing. This allows for the identification of interpersonal boundaries as well as task behaviours. The establishment of dependent relationships with other group members occurs, or may result in the attachment of pre-existing standards to group members (Smith, 2005). The process of forming is therefore that of orientation, testing and dependence allocation. In the first stage of team building, the forming of the team takes place (Smith, 2005).

STORMING

Storming occurs once the individuals have identified dependencies or pre-existing standards. The individuals resist group influence and task requirements, as the sequence is plagued by conflict and polarization around interpersonal issues as well as a reluctance to commit to the tasks at hand. The storming phase, though uncomfortable, is imperative to the growth of the team (Smith, 2005). There have been instances where the team never moves past the storming phase, and will continue to argue over large, but also, inconsequential tasks. Tolerance and patience are testing during this phase, and maturity plays a significant role on transferring to the phase of Norming.

NORMING

As the storming phase calms, cohesion and in-group unity develop, and resistance is overcome. This allows for new roles to be adopted, standards to evolve, as well as allow the expression of personal opinions without complete reluctance. In some instances, individuals will refrain from expressing any conflicting ideas and will accept the status-quo of the group (Smith, 2005).

PERFORMING

Roles within the group become functional and flexible, as interpersonal structure becomes the tool of tasks. The energy of the group is channelled into common goal. As most structural issues have been resolved, the group members now become supportive of each other and the performance of the task (Smith, 2005).

Adjourning

Adjourning was not considered in the initial model of group development, but has since been identified as the dissolution phase. It concludes the termination of roles, tasks and reduces the dependencies created between members (Smith, 2005).

Discussion and Assessment

While Tuckman's model of group development has been used for over 20 years, new models have arisen such as stage theory. It has been noted that several new theorists have simply renamed the phases and amended the constituent of each phase marginally (Smith, 2005).

There are several critiques to Tuckman's model, in that it is too straightforward, and leaves no space for variability characterising of human interaction (Smith, 2005). Deviations and overlap may be seen between phases, as some may continue displaying the behavioural traits identified in the previous phase whilst others are omitted completely. The linearity of Tuchman's model has also come under scrutiny, with certain theorists identifying that the formulation may be more cyclical in nature, with the emphasis on the movement between norming and performing highly cyclical (Smith, 2005).

The White-Fairhurst TPR Model was created using Tuckman's model as a foundation. However, the sequence Forming-Storming-Norming were grouped together and renamed as the Transforming phase, which was considered the initial performance level of the group. The Performance phase followed, and leads to a reforming phase, which was cyclical in nature. (White, 2009). Similarly, Peck developed phases for larger scale groups, and identified the phases as pseudo-community, chaos, emptiness and true community. Although the phases bare a similarity to Tuchman's phases, the Peck phases were for communities rather than small groups of individuals (Peck, 1987).

In conclusion, it is found that Tuchman's model is adequate for small groups, which tend to follow a predictable path. It is also used in several project management programs to gain a fundamental understanding of group dynamics, and will be used in the discussion of this research in regard to effective communication (Smith, 2005).

2.9 Summary of Literature Review

The Literature Review introduces the Engineering Council of South Africa, and identifies the ECSA ELO 8 requirements. Cross-disciplinary studies are then introduced, and the differences between the types of cross-disciplinary study identified. Group Formation is explored, and different theories identified. Multidisciplinary/Interdisciplinary studies are discussed in tertiary education, and the critique of the inclusion into tertiary studies is established. Guidelines and lessons learnt from the CPSU are discussed, and the overlap between the requirements of the two tertiary bodies identified.

Systems Engineering and Management (MECN4020) at Wits University is then presented. A breakdown of the course is given. The introduction of the theoretical approaches to Systems Engineering is given, as identified by INCOSE. The history and importance of Systems Engineering is discussed, and the "Systems Approach" established. The piecemeal approach is discussed, and the systems approach in an engineering context is discussed. Prior interdisciplinary learning and Systems Management courses are identified at its University, and the findings of the lecturer stated. In light of the requirements for a systems approach, the processing of information across a boundary is discussed, with the differences between syntactic, semantic and pragmatic processes established.

A pilot study's findings are elaborated on, so that the researcher may compare the emergent findings of this research with the pilot studies' findings.

Finally, the design of multidisciplinary study in the education system is discussed, with fundamental requirements identified so that interdisciplinary study is seen to have the fundamental building blocks. Critique is given on the current controversial approaches to multidisciplinary study.

Points to consider during the coding were as follows:

- ECSA ELO 8 Requirements
- Multidisciplinary tasks require co-operation across at least one disciplinary boundary
- Group formation and communication
- Systems vs. piecemeal approach
- Pilot Studies' findings (emergent themes)
- Critical failure points

3 PROPOSED METHOD

The research required is that of complex logic reasoning through inductive and deductive logic (Cresswell, 2007). The inductive-deductive logic process means that the researcher uses complex reasoning skills throughout the process of research.

3.1 Qualitative versus Quantitative Analysis

The field data considered in the proposed research is based on the reflections of students and their experience of the course MECN4020 – Systems Engineering and Management (Sunjka, 2011a) (Sunjka 2012) (Sunjka, 2013).

Initially, a systematic subjective approach is to be used, so that the researcher understands the experiences of the students, so that insight is gained, and the complexity, richness and depth of the phenomenon is understood (The University of Missouri 2014) (Fereday & Muir-Cochrane 2006). Dialectic and inductive reasoning will be used, so that the interpretation of the student reflection is inductive of the shared interpretation and experience of the student (The University of Missouri 2014) (Wolfe 2003). The a priori approach is therefore qualitative, and several methods of qualitative methodology are therefore considered and evaluated in the suitability to the determination of the phenomenon that is the students' experience (Fereday and Muir-Cochrane, 2006).

Quantitative analysis is considered as a formal, systematic process that is followed so that a relationship may be described, tested and examined for cause and effect (The University of Missouri, 2014) (Cresswell, 2007). It is reductionist, and uses logistic and deductive reasoning, using numerical data as a basic element for analysis. Statistical analysis is used so that a generalisation or inference may be stated (The University of Missouri, 2014).

The approach to the research is therefore qualitative, as the field data's basic element is words of students, and not numerical data. As the requirement is that of subjective and holistic deduction, quantitative research will be used after qualitative research, in areas where the deductions made from qualitative research may be quantified (The University of Missouri, 2014).

The philosophical assumptions and interpretive frameworks as well as the design of the study were taken from several sources (Cresswell, 2007). (Guest, MacQueen and Namey, 2012).

3.1.1 LITERATURE REVIEW CONSIDERATIONS

Several components of the literature review are considered during both inductive and deductive methods. The norms of multidisciplinary study where noted and observed during the coding, as well as the observation of critique surrounding multidisciplinary study.

Points considered during the coding were as follows

- ECSA ELO 8 Requirements
- Multidisciplinary tasks require co-operation across at least one disciplinary boundary
- Group formation and communication
- Systems vs. piecemeal approach
- Pilot Studies' findings
- Critical failure points

3.1.2 RATIONALE FOR THE RESEARCH APPROACH

The key objective of this research was to evaluate whether the group project for MECN4020 effectively ensures that students meet the requirements of ELO 8. This was proposed to be evaluated through an analysis of written reflections of students of their experience of the course MECN4020 – Systems Engineering and Management.

A combination of quantitative and qualitative methods is used as the term "mixed methods" research is used, referring to all procedures collecting and analyzing both quantitative and qualitative data in the context of a single study (Driscoll *et* *al.*, 2007). Qualitative research is multi-method in focus, involving an interpretive, naturalistic approach to its subject matter, whilst quantitative research gathers data in numerical form which can be analysed using specific methods (McLoed, 2007) . The raw data in the form of the student reflections is thus qualitative in nature. There is no need to explore the types of research designs / approaches or data collection strategies, as the raw data is pre-determined.

This approach describes transformative mixed methods research designs. The designs fall on somewhat different ends of the mixed methods collected. The first is a relatively simple design in which qualitative and quantitative data are collected concurrently. The other is a fairly complex sequential design.

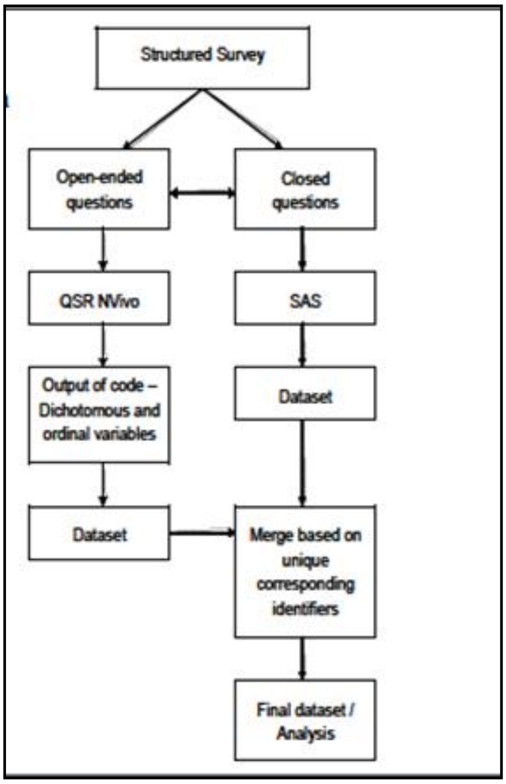


Figure 3-1: Mixed Method - Inductive and Deductive *(Driscoll* et al., *2007)*

3.2 Qualitative Analysis

There are several approaches to qualitative research, namely (The University of South Alabama 2014) (The University of Missouri 2014) (Bogdan, R. Biklen 2007) (Cresswell, 2007) (Guest, MacQueen and Namey, 2012) (Cresswell, 2007):

- Researcher as a Multi-culturist Specialist
- Theoretical Paradigms and Perspectives
- Research Strategies

The method is prescribed in the student feedback, as the reflection is completed without the research being able to the method used when collected. Therefore, only analysis is considered for inductive analysis. A comprehensive analysis of each method may be found in Appendix C.

Table 3-1: Comparison of Qualitative Method and Analysis

Method / Analysis Type	Description	Disqualifying Criteria
Method	The Researcher as a Multi-culturist Specialist	As this research will not be displaying names nor investigating history, tradition or concepts of the self (Cresswell 2007), it is deemed redundant.
Method	Theoretical Paradigms and Perspectives	As this research will not be investigating cultural diversity and social theories, it is deemed redundant (Cresswell 2007).

Method / Analysis Type	Description	Disqualifying Criteria
Method	Research Strategies	The design strategy is beyond the researchers control as the data is collected in a pre-described manner. The strategies of Life history, Historical Method, Action and Applied Research and Clinical Research are excluded from the research strategies to be scruitinised (Guest et al. 2012)(Cresswell 2007).
Analysis	Narrative	Although the concept of Narrative research is strong, researchers should collaborate with participants by actively involving them in the research, as its biggest advantage is collaboration between the researcher and the researched. It requires that the researcher have keen insight into the individual’s life (Cresswell 2007). It is thus not suited to this research.
Analysis	Phenomenology	Phenomenology limits the in-depth interviews to 10-15 people (Cresswell 2007), and is therefore not suited to the scope of this research (The University of Missouri 2014)

Method / Analysis Type	Description	Disqualifying Criteria
Analysis	Grounded Theory	One of the requirements of Grounded Theory is that the primary form of data collection, in which the researcher has the ability to return to participants with new interviews and also requires a process or action (Cresswell 2007). Ground Theory is thus not suitable for this research.
Analysis	Ethnography	Ethnography is main concerned with the discovery and description of the culture of a group of people, and is not seen as relevant to the research to be conducted for this dissertation (The University of Missouri 2014) (Cresswell 2007).
Analysis	Case Study	One of the challenges when using Case Study Strategy is that the researcher must consider whether to study one or multiple cases. The more individual case studies, the less the depth in any single case. Multiple cases are limited to five. For this particular research, the amount of variables (year, branch, case study type) would yield the results too insignificant (Cresswell 2007).

Method / Analysis Type	Description	Disqualifying Criteria
Analysis	Thematic Content Analysis	It allows for both an inductive and deductive research, and therefore makes the process of thematic analysis appropriate for the analysing of data, when the purpose is to extract information to determine the relationship between variables, as well as the comparison of varying sets of data that pertain to different situations within the same study, as defined by the researcher's aim (Guest et al. 2012) (Ibrahim 2012a).

SUMMARY OF RESEARCH STRATEGY

As the researchers aim is that of both inductive and deductive analysis, a combination of Grounded Theory and Phenomenology could be used. However, it has been established that Thematic Content Analysis (TCA) considers both inductive and deductive analysis. There are several parallels in Grounded theory and TCA, Grounded Theory is deemed unsuitable for researchers who wish to compare two separate sets of data that are gathered at different times as well as unsuited to very large groups (Cresswell, 2007) (Ibrahim, 2012a). Phenomenological Analysis is another method used to focus on interpreting data, but is also deemed unsuited to this project, as it is not appropriate for analysing data that focuses only on a participants visions and issues (Ibrahim 2012).

3.2.1 THEMATIC CONTENT ANALYSIS

Thematic Content Analysis (TCA) has been described as a comprehensive process, where researchers are able to identify numerous cross-references between the data the research's evolving themes. (Haynes, 1997). It allows for both an inductive and deductive research, and therefore makes the process of thematic analysis appropriate for the analysing of data, when the purpose is to extract information to determine the relationship between variables, as well as the comparison of varying sets of data that pertain to different situations within the same study, as defined by the researcher's aim (Guest, MacQueen and Namey, 2012) (Ibrahim, 2012b).

Criticism and Barriers

For Thematic Content Analysis (TCA), large amounts of data are often collected, and data collection and its analysis overlap, resulting in no distinction between the data collection and its analysis. (Manion, L., Morrison, K., 2011).

Traditional methods may be utilized for the analysis of the data, but several statistical programmes are available for thematic analysis, including NVivo, MAXQDA, T-Lab, Saturate or Atlas (Khandkar, 2009)(Cresswell, 2007). The use of programmes eliminates the researchers impression of the data, thereby improving the rigour of the analytical steps for validation.(Ibrahim, 2012b). There is criticism for the use of non-manual analysis, in that it limits the creativity and fluidity that themes might emerge (Ibrahim, 2012a).

Thematic analysis allows for the determination of the relationships between concepts, and compares them with replicated data. All possibilities for interpretation are possible, as various concepts and opinions of the students can be gathered. TCA is appropriate for this particular project, as it allows both inductive and deductive methodologies. TCA also requires a large amount of data to present content and allow for the researcher to get a sense of the predominant and important themes (Ibrahim, 2012a).

Thematic Content Analysis will, therefore, be used for qualitative objectives. The frequency of the requirements met as required by ECSA will be analysed thereafter, and hypothesis will be accepted or rejected based on the outcome. Several themes are therefore already defined whilst other themes are to be revealed.

3.3 Research Analysis

The research to be conducted is both exploratory and explanatory, and is therefore a mixed research design (Guest, MacQueen and Namey, 2012). It will therefore be both hypothesis testing in terms of |ECSA outcomes, but also "hypothesis generating" in that it will identify themes and subthemes.

3.3.1 DATA SOURCES

Reflection requests are given along with a project brief and are therefore the tool to be used to collect data. The nature of the feedback is shown below, using an excerpt from the project brief given (Sunjka, 2011b):

"As individuals, reflect on the experience of working in an inter-disciplinary group i.e. how did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc."

"Based on your reflections, each group member is to write about 300 words on their own individual experience of working in an inter-disciplinary group. These should be included in the appendices of your written report."

3.3.2 DATA COLLECTION TECHNIQUES

The provision in the project brief was used to gather students' opinions and feedback as this is most suitable for gathering descriptive information. This was done so that:

- Large amounts of information at a low cost per respondent can be collected
- Respondents may give more honest answers as they are not limited to particular vocabulary or pre-empted answers by prompted questions as is normally found with pre-populated forms and evaluations.
- No interviewer is involved to bias the respondent's answers.

Reflections from all students registered for the subject "System Engineering and Management" were emailed from the lecturer for the years 2011, 2012 and 2013. All reflections were checked against a corresponding class-list. Each transcript was then re-typed in Microsoft word so that any demarcations made by the lecturer would not bias the analysis required for emergent themes. The student number of each reflection was used as a reference to the class-list, as many students used their middle name rather than their first name. There were also instances where the surname was used as a first name by the university, and data collection and capturing was therefore time-consuming and problematic.

To meet the requirements for a priori, all transcripts were then copied and pasted into an Excel spreadsheet, with all categorical data corresponding. Several students had their race and gender updated accordingly. Each student was assigned categorical data, such as case study, branch of engineering, gender, race, mark received and number of group members, although some of these traits were assigned using social understandings of the students name, rather than having the biographical data on hand.

In instances where the gender or race determination were ambiguous, the categorical data was labelled unknown. Therefore, there were students who had first and/or last names that were ambiguous in nature and the researcher was unable to define the exact biological traits of every single student. These traits were not used in the analysis itself, but are stored within the project in the event of future research requirements.

3.3.3 Inductive Research

Initially, analysis will start with inductive analysis, so as to observe the a priori pre-requisite whereby the data had not been analysed previously , (Fereday 2006) (Eda 2006). Certain considerations are required:

- Code List / Hierarchy
- The Size of the Coding
- A Priori
- Coding Method
- Measurement of Cluster Quality

Code List or Code Hierarchy

It is imperative to create each code with a standard definition: definitions must have the label or name of the code, date when coding was done or changed, definition of the code and the analytic idea it refers to, as well as ideas about how it relates to other codes (Bryman and Gibbs, 2008). This is of utmost importance as it (Guest, MacQueen and Namey, 2012)(Cresswell, 2007):

- Separates codes from the documents
- May be hierarchical
- Used to apply the code in a consistent way and to share with others.

The size of the coding:

There are advantages and disadvantages to both high and low level coding (Bryman and Gibbs, 2008)(Guest, MacQueen and Namey, 2012)(Cresswell, 2007):

- High level: Maximize usefulness of code – applied to enough chunks to justify re-contextualization and avoids prejudicing later analysis. However, few episodes can be identified to match code, and it includes lots of less relevant material, with the coding quite vague.
- Narrow/detailed: Greater differentiation, clear definition and easier to identify chunks in text. However, important contextual data may be lost, the loss of meaning, and may end up with too many codes to remember.

A Priori Requirements

A priori requirements may be delimited to the following (Statistical Services Centre, 2001):

1. Deciding on the facets which need to be included to give a good feel for the concept i.e. the leading questions given by the lecturer.
2. Tying these to the questions or observations needed to measure these facets i.e. emergent themes
3. Ensuring balanced coverage, so that the right input comes from each facet
4. Working out how to combine the information gathered into a synthesis which is sensible.

CODING ANALYSIS

Open coding is breaking down, examining, comparing, conceptualising and categorizing data and used will be used to identify further themes. This may be done using the following methodology (Guest, MacQueen and Namey, 2012) (Bogdan, R. Biklen, 2007a):

1. Identify word frequency criteria to identify major themes
2. Sort words and related words into categories or themes
3. Re-examine the data to examines how information was assigned to a theme
4. Name and define the theme
5. Re-examine supporting data to finalise
6. Underlying meaning of the theme.

This analysis falls in line with the argument that data must be read at least twice so that the researcher develops an understanding of the content, as suggested by (Bogdan, R. Biklen, 2007b). This allows the researcher to appreciate the full picture and make connections between the participants thoughts and ideas, as well as the prevention of precipitous conclusions (Ibrahim, 2012b). It recommended that the themes should be identified by highlighting sentences from each participant, whilst keeping an eye on the ECSA ELO 8 requirements during data collection and analysis.

A word frequency query will be run for the overall project sample, and emergent themes and correlated subthemes will be identified. Emergent themes will then be coded for within each reflection. Emergent themes will then be shown using dendograms and clusters of subthemes using cluster analysis, which is a form of vector space representation (Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, 2014).

MEASUREMENT OF CLUSTER QUALITY

Two measures of cluster “goodness” or quality are used. Internal quality measure is defined as a type of measure that allows us to compare different sets of clusters without reference to external knowledge (Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, 2014). External quality measures are defined as the evaluation of how well the clustering is working by comparing the groups produced by the clustering techniques to known classes. (Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, 2014).

Entropy will therefore be measured by either providing a measure of "goodness" for un-nested clusters or for the clusters at one level of a Hierarchical clustering (Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, 2014).

A Pearson's correlation coefficient will be derived for each cluster created, to identify the strength of the emergent theme with the project sample. Pearson's correlation was chosen as a good measure of correlation. Cosine, Pearson correlation and extended Jaccard similarities emerge as the best measures to capture human categorization behaviour, while Euclidean measures perform poorly. It was found that the Jaccard and Pearson coefficient measures find more coherent clusters (Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, 2014).

The Jaccard correlation coefficient was considered, but was found to be limiting within the scope as Pearson correlation coefficient is slightly better as the resulting clustering solutions are more balanced and is nearer to the manually created categories (Tanis, 2006).

3.3.4 DEDUCTIVE RESEARCH

A priori is again noted as a pre-requisite, and is met as the reflections have not been measured against the requirements of the ELO 8. The proposed methodology for deductive analysis (ECSA requirements) will then be aligned with the best practise , which advises that three principles are to be adhered to, so as to ensure more efficient outcomes (Denscombe, 2010a):

1. Compact the extensive and raw data into a succinct structure, by organising the data into charts and tables, so that the researcher may identify, compare and determine the data upon which to focus.
2. Create a relationship between the research objectives, and ensure that the summary is clear

3. Conclude by developing a model and improving the conceptual basis of the research.

Following similar principles, previous analysis (Sunjka, 2011b) showed that the analysis will start with predefined themes as required by ECSA. Additional methods used outside of the prescribed steps by best practice will include (Denscombe, 2010b):

1. Recapture all of the students' reflections on Microsoft Word, so that no bias may be introduced by the demarcations made by the lecturer.
2. Allocation of categorical data to the student number, so that no bias may be created due to the student's gender, marks, discipline or race.
3. Import of reflections into NVivo along with categorical data
4. The creation of 'nodes' – each requirement of ECSA will be defined with a clear understanding of what constitutes a Yes / No / Unsure / Not Clear
   Yes – The student meets the ELO8 requirement
   No – The student does not meet the ELO8 requirement
   Unsure – The researcher finds the student reflection contradictory
   Not Clear – The researcher cannot code the student reflection

3.3.5 COMPUTER ASSISTED ANALYSIS

Computer programs assist with the storage and organisation of the data. When using the program, the researcher works through the material line by line and deciphers which parts of the data they would like to allocate to pre-defined nodes, also known as themes. These nodes are set up by the researcher themselves. After reviewing all the data, the researcher is then able to use the search function of the software to locate all the text associated with that particular node or label. (Cresswell, 2007).

A node may contain sub-nodes, also pre-defined by the researcher. This further helps to extrapolate the data into sub-sections. Once this is complete, the researcher is able to interrogate the database about the interrelationship among nodes and sub-nodes. It is important to note that the software itself does not complete any of the coding. The researcher has to label all the data and then draw graphical and statistical data from the software.

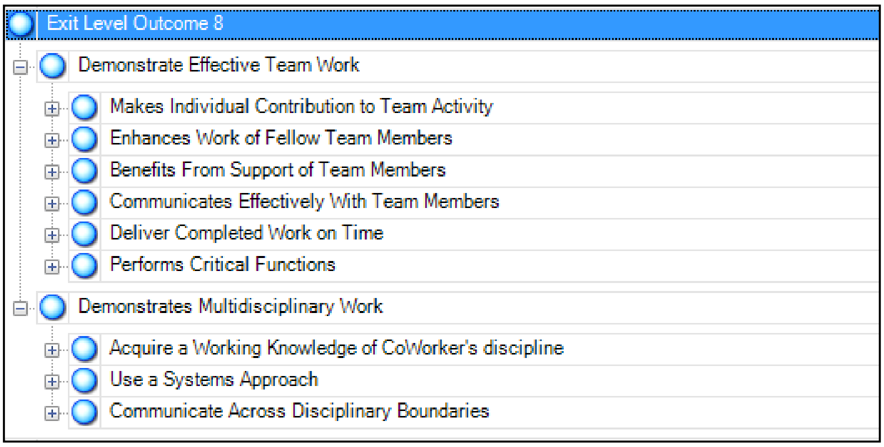


Figure 3-2: ECSA Node Creation in NVivo

The above approach meets the conditions of a priori as the researcher will (Statistical Services Centre, 2001):

1. Create nodes for the requirements of ELO 8
2. Analyse the data by clustering them by expected themes.
3. Start the coding by analysing each reflection from an individual based on the ELO 8 criteria. This is done by coding the reflection as “Yes” if it meets the ELO 8 criteria and “No” if it does not. If the researcher is unsure, the text coded is labelled as “Unsure”
4. Ensure balanced coverage, so that the right input comes from each facet i.e. coding for “Yes”, “No” and “Not Clear” as well as noting reflections that are cannot be coded.
5. Combine the information gathered into a synthesis which is sensible.

This is a high level description of the actual analysis. Further information is given later.

3.4 Conceptual Framework

The theoretical approach shown above is elaborated on by the research framework created by the researcher. As no closed questions were asked, an adapted research framework is shows the inductive and deductive methods utilized below:

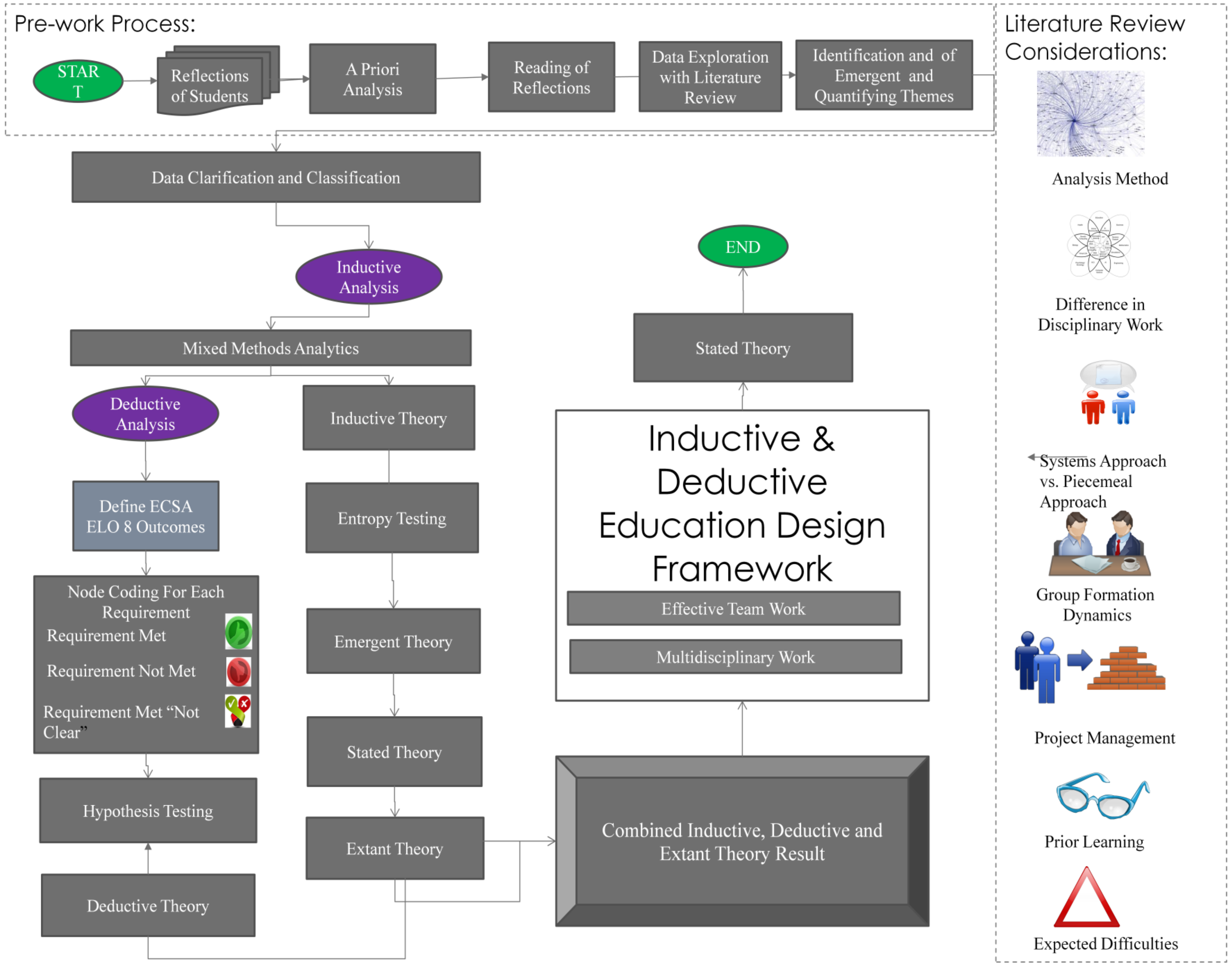


Figure 3-3: Conceptual Framework

3.5 Issues of Reliability and Validity

3.5.1 QUALITATIVE DESIGN

Qualitative design focuses on credibility, transferability, dependability and conformability (Gibbs, 2012). Statistical analysis of the measurement system is needed to indicate the reliability of the researcher's measurement system, and requires that both the reliability and validity of the measurement system be proven. Four main facets concerning the quality of research are to be considered (Gibbs, 2012):

Reliability – If the investigation had been carried out again by different researchers, would the same results have been obtained? Can be negatively impacted by subject error (different results on different days), subject bias (try to please researcher) and observer error and bias (Fereday and Muir-Cochrane, 2006).

Internal Validity – The extent to which a research design and the data it yields allow the researcher to draw accurate conclusions about relationships within the data. Does the evidence reflect the reality under investigation? Has the researcher found out what he/she thinks or claims it's about? Repeating students are excluded from the study due to the risk of regression (Wren and Phelan, 2005).

External Validity/Generalizability – This is a measure of the extent to which a research study's results apply to situations beyond the study itself. It questions what relevance the results have beyond the current research. This can be negatively impacted by selection:

- Specific to group – typical of volunteers
- Setting (specific to setting)
- History (particular past experience)
- Construct effects (only this group has these constructs) (Gibbs, 2012).

Credibility – Is there sufficient detail on the way the evidence was produced for the credibility of the research to be assessed? (Gibbs, 2012)

RELIABILITY

Reliability may be tested by evaluating test-retest reliability and parallel forms reliability (Wren and Phelan, 2005).

"Reliability may also be defined as the extent to which a questionnaire, test, observation or any measurement produces the same results on repeated trials" (Miller, 2003). In short, it is the stability or consistency of scores over time. There is a variety of different types of reliability that each has multiple ways to estimate reliability for that type. For the purposes of this research project, the Internal-Consistency Method will be used, as the student's complete project during one time period. "Internal consistency concerns the extent to which items on the test or instrument are measuring the same thing" (Miller, 2003).

Although students were not prompted to rate the level of multidisciplinary work required, responses can be used to gauge whether multidisciplinary and/or interdisciplinary studies were required in this subject, and a dichotomous (Yes/No) answer may be revealed. When no evidence is available to select a dichotomous response, the researcher will assign a "Not Clear" response. For this reason, this is the easiest form of reliability to investigate (Statistical Services Centre 2001).

The sample data will therefore be explored to ascertain whether any patterns emerge when students' answers are coded as "Not Clear". It is to be noted that the hypothesis analysis will only use the dichotomous scale of Yes/No and therefore follow binary analysis, with "Not Clear" results considered as part of the population and not the sample. It is impossible for the researcher to define the data set as a population, as many parts of the individual reflections may be coded "Not Clear".

The test-retest reliability of the research will not be tested, as the time required for such testing versus the perceived benefit from performing the required test is weighed. The size of the sample being tested (n=470) is well beyond the requirements for qualitative analysis (n=250) (Statistical Services Centre 2001).

The reliability of the measurement instruments (inference) may be proven by using three different methods of calculating confidence interval inference (Agresti and Coull, 1998).

VALIDITY

"Validity is defined as the extent to which the project measures what it purports to measure" (Miller, 2003). There are many different types of validity, including: content validity, face validity, criterion-related validity (or predictive validity), construct validity, factorial validity, concurrent validity, convergent validity and divergent (Fereday, 2006). For the purpose of this study, only Ex-Ante validity and Content Validity will be tested.

1. Face Validity – this requires asking the participants whether they thought that the project was well constructed and useful. This information may be gauged directly from the data given. By constructing Node/Theme qualifiers, the researcher aims to increase the face validity.
2. Ex Ante validity – do the questions asked in the assignment properly inform students of what is required?

FURTHER RIGOR

The use of the researcher's personality may be used, in that the involvement with the subject's experience may be considered, as well as the coding saturation of the data. Bracketing is considered vital, so that the researcher suspends what is currently known about the phenomenon (ECSA ELO 8 requirements as well as extant literature), so as to meet the requirements of a priori, keeps an open concept, and sets aside their own preconceptions (The University of Missouri, 2014) (Tanis, 2006). Clustering and categorising of data, the examination of concepts and themes, as well as the definition of relationships between or among concepts is seen as rigor of the data analysis (The University of Missouri, 2014) (Cresswell, 2007).

ECSA requires that both effective team work and multidisciplinary work are required for the Exit Level 8 Outcome (Engineering Council of South Africa, 2003a). The following section is dedicated to the theory and understanding of each requirement and the guidelines to coding for each, so as to ensure the internal consistency of the researcher.

3.5.2 NODE/THEME QUALIFIERS

Theme qualifiers were created so that each decision made by the researcher was clear and concise. During the analysis, several reflections gave no indication of whether a requirement had been met, and no coding could be done. In instances where the reflection was ambiguous i.e. the student was not clear in their reflection regarding certain requirements, or the researcher felt that the reflection was contradictory, the requirement was coded as "not clear". Where there is no reflection content for a requirement, no coding will occur. The absence of coding will be taken into account during the analysis of the results.

FOLLOWING BEST PRACTICE FOR CODING:

Each theme is broken down into unambiguous, mutually exclusive and exhaustive, categories so that any response segment can be assigned to just one, and assigned the corresponding code value. A "codebook" is then prepared where the categories are listed and codes assigned to them. Codes do not have to be consecutive numbers. It is common to think of codes as presence/absence markers, but there is no intrinsic reason why they should not be graded as ordered categorical variables if appropriate (Statistical Services Centre 2001), e.g. on a scale such as "Yes", "No", "Not Clear" and noted reflections that could not be coded.

For the purposes of the deductive analysis required for the ECSA Outcomes Level 8, the following qualifiers were used, as identified in the following section:

3.5.3 The Candidate Demonstrates Effective Team Work by the Following:

Makes individual contribution to team activity

Student acknowledges their own personal input into the project from their own discipline. This is not to assume that the input was included in the final solution of the case study, but rather, that the individual gave insight to the group from their perspective discipline. An individual contribution may not necessarily be considered a critical function. The individual may make an effort but may not contribute to the project from their perspective disciplines, but may serve an administrative function. A critical function, however, shows that the individual's contribution is from their perspective discipline and therefore will qualify as an individual contribution.

Table 3-2: Coding Qualification for Individual Contribution Criteria

Coding	Qualification	Excerpts
No	Student expresses that they had never discussed their individual findings with the group, performed no critical functions, or were side-lined completely.	"I did not feel like I was taken seriously. "
Not Clear	Student makes no mention of individual expression. No form of individual contribution is discernible from the reflection but coding is can be completed to identify that it is not clear.	"members of the group seemed to be convinced with the quality of their contribution to the solution"
Yes	Student mentions individual contribution either from input from their discipline or performs critical functions. Assignment to each member of the group is seen as individual contribution.	"This challenge was overcome by extensive individual research and preparation prior to group meetings"

PERFORMS CRITICAL FUNCTIONS;

Student is assigned a critical task that is required for the completion of the project. The critical task is not required to come from the students' relevant discipline, but rather, is considered pivotal to the completion of the project. This may include several facets including project management functions.

Table 3-3: Coding Qualification for Critical Tasks Criteria

Coding	Qualification	Excerpts
No	Student expresses that they did not contribute tasks required for the completion of the project, or expresses that their efforts were not taken into consideration. Alternatively, student is excluded or excludes themselves from the project	"… as no one had the time to spare to redo their own section."
Not Clear	Student makes no mention of performing critical tasks or it is not discernible whether student performed critical tasks but coding is can be completed to identify that it is not clear.	"As a result the work was delegated between the students from the two schools"
Yes	Student expresses that they did contribute tasks required for the completion of the project. Evidence of the assignment of tasks critical to the completion of the project is seen as performing critical functions. Any form of conflict resolution that would otherwise have resulted in the project not being completed is also seen as performing a critical function.	"… coordinate and delegate tasks equitably to each member …"

ENHANCES WORK OF FELLOW TEAM MEMBERS;

There is sufficient evidence to suggest that the student played a role in the enhancement of the project administration and/or assistance in fellow students understanding of the case study. This requirement is difficult to ascertain from the reflection, as students are instructed to reflect on their experience with the group, and as such, will not necessarily expressly identify their role in the enhancement of the project.

Table 3-4: Coding Qualification for Enhancing Team Member's Work Criteria

Coding	Qualification	Excerpts
No	Student acknowledges that they were not able to assist other team members.	“Even if I had a good point to argue, if the majority of the group members disagree with what I am conveying then I just had to accept that for the sake of time.”
Not Clear	Student makes no mention of enhancing the work of fellow team members or no evidence is found within the reflection that the student enhanced the work of team members, but coding is can be completed to identify that it is not clear	“Even if I had a good point to argue, if the majority of the group members disagree with what I am conveying then I just had to accept that for the sake of time.”

Yes	Student expresses specific tasks completed to assist fellow team members including but not limited to performing critical functions, taking a leadership role, resolving conflicts, teaching new methods or techniques or explaining terminology and/or systems.	“I was happy that I could contribute to the group by explaining some of the electrical terminology and systems”

BENEFITS FROM SUPPORT OF TEAM MEMBERS;

There is sufficient evidence to suggest that the student benefitted from other students, whether it was from an enhanced understanding of subsystems of the project or project management principles itself. Other areas to include would be decreased workload, critical functions in the very nature that they could not be done by the individual and effective communication -when evident that the student facilitated such communication.

Table 3-5: Coding Qualification for Benefits from Support of Team Members Criteria

Coding	Qualification	Excerpts
No	Student identifies that their overall progress and understanding was hindered by team members. Alternatively, the student expresses that they did not benefit from any team members whatsoever. It is to be noted that a student mentioning that they did not benefit from a particular member does not substantiate total lack of enhancement by other team members.	” I struggled to work with group members who had a different work ethic to my own and the project suffered at times due to the differing attitudes of members in the group”
Not Clear	Student makes no mention either tacitly or expressively of work enhancement by other team members, but coding is can be completed to identify that it is not clear	“Getting contributions from other members was also hair raising at times. “
Yes	Student identifies that their overall progress and understanding was enhanced by team members. Alternatively, the student identifies areas where they were assisted by team members. It is not required that the student is assisted by every member of the group, as the ECSA requirement stipulates a single source of enhancement.	“It was appreciated how efficient joining forces with different engineering disciplines to outflank and put into scrutiny a given problem is. “

COMMUNICATES EFFECTIVELY WITH TEAM MEMBERS;

Effective communication is to be derived after the stages of forming, storming, norming and conforming have occurred. It is therefore the identification of whether the student experienced the conforming part of group dynamics, or whether the group was stuck in the storming phase of group dynamics. Any methods used to overcome the storming aspect of group dynamics should be weighed against the overall outcome to ascertain whether effective communication occurred. This may be identified by students finding new methods to communicate, using technology to facilitate meetings, and clarifying roles within the group. Effective communication should not be confused with "Communicates across Disciplinary Boundaries"

Table 3-6: Coding Qualification for Communicating Effectively with Team Members Criteria

Coding	Qualification	Excerpts
No	Student identifies that group failed to move past the storming phase of group dynamics and that communication did not occur, or student expresses withdrawal from the group.	"Unfortunately , I encountered remarks such as "we are far more busy than you are" or "Our course is more demanding than yours" and other such comments .I assumed that in fourth year engineering, the group members would take responsibility for their actions and not shift the blame"

Not Clear	Student identifies the storming phase of group dynamics and does not mention any form of norming/conforming, but identifies that the project was a success, and coding is can be completed to identify that it is not clear	"we also brought in personal feelings into the matter, therefore affecting the progress of the project even further"
Yes	The overall group dynamic moves past the storming phase, and examples of successful efforts around communication barriers are mentioned. Efforts may be technological aids, changing group dynamics and suggestions of resolutions to disputes.	"Communication initially between members was "far and wide" but as time went on this issue was resolved through the appointment of a group leader. This created structure and allowed meetings to run cohesively."

DELIVERS COMPLETED WORK ON TIME.

The requirement of work completed on time may be considered positive if the student verbalises that the project was handed in by the due date or before, or if the student indicates that they were satisfied with the end report handed in. This criterion may be stated in several areas of the reflection, and the combination of several opinions may be combined to identify the requirement of completed work on time.

Table 3-7: Coding Qualification for Completing Project on Time Criteria

Coding	Qualification	Excerpts
No	The student is not satisfied with the project outcome, or mentions that the group ran out of time	”The group work was not at the quality required for such a project, but I was constrained to make the changes I felt necessary since the project was a combined group effort, as opposed to an individual effort I strongly felt that the other members had made their contribution sooner that the project would have been of a higher standard”
Not Clear	No mention is made of the project being completed on time, and satisfaction or lack thereof cannot be deciphered from the reflection, yet coding is can be completed to identify that it is not clear	”The initial target to complete the project as soon as possible was not met due to overwhelming workload from other commitments”
Yes	The student verbalises that the project was handed in on time, completed beforehand, or alternatively, that they were satisfied with the project outcome.	“work was submitted, as expected on time”

3.5.4 THE CONTEXT OF PROCESSING WITHIN MULTIDISCIPLINARY STUDIES

Multidisciplinary studies use a combination of semantic and pragmatic processing (Klein, 2008), and thus the ECSA Outcomes Level Multidisciplinary requirements are much more intricate, and therefore difficult to discern. The entire reflections, rather than parts of the reflection, are to be examined so as to identify whether the three requirements are met. Each requirement has a complex section of sub-requirements. It is therefore imperative that these requirements are only coded once the entire reflection is read, and the reflection of the researcher is needed to ascertain whether a combination of criteria have been met satisfactorily for each requirement to be considered as achieved.

3.5.5 THE CANDIDATE DEMONSTRATES MULTIDISCIPLINARY WORK BY THE FOLLOWING:

COMMUNICATES ACROSS DISCIPLINARY BOUNDARIES.

Communication across boundaries requires instances that show a syntactic, semantic and pragmatic transfer, translation and/or transformation of information from one discipline to another (Carlile, 2004). Simply put, it is required that students do not only convey their knowledge (effective communication), but that they also understand and assess each other’s knowledge, thereby creating a platform of “common knowledge” between each other. Communication across a disciplinary boundary is considered distinctly different to effective communication. Effective communication can be achieved using syntactic processing and may not require semantic or pragmatic processing per se (Carlile, 2004).Adjectives that are indicative of communication across disciplinary boundaries include consensus, agreement and explanation. Scepticism should be used when the reflection indicates that the project ran smoothly and quickly, as the amount of effort required to adequately share and assess another disciplines increases with the translation of discipline specific knowledge (Ramo and St Clair, 1998). This is also known as the difference of knowledge at a boundary (Carlile, 2004).

Table 3-8: Coding Qualification for Communication across a Disciplinary Boundary Criteria

Coding	Qualification	Excerpts
No	The student expressly states that they did not communicate across a disciplinary boundary. Alternatively, the student works in isolation and do not require a need for consensus. No mention of explanation, sharing and access to another disciplines input or skill is mentioned. The overall feedback of the student is that of isolation of ideas and/or principals. No form of argument is apparent.	"The communication differences were mainly due to the different nomenclature used by the different members of the group as we are all from different schools of thought. This resulted in key decisions not being taken on time and action differed".
Not Clear	The student mentions requesting information and/or skills from other disciplines, but it is not clear whether the student receives any aid. There may be mention of arguing, trying to reach a consensus. It is not clear that the student has engaged outside of his own discipline. Coding to identify that it is not clear	"The result was a highly complex and complicated system required to link and schedule tasks. Only at the point at which this situation was reached was the decision made to backtrack and perform the layout in a chronological manner- losing a full 8 hours of work."

Yes	The student expresses that they had learnt from other students disciplines, indicates arguments may have occurred, that different perspectives were weighed, their initial approach had changed or mentions identifying issues they had not initially considered. Words like consensuses as well exposure to different ways of thinking.	"Through discussion with the group, any ambiguous knowledge areas were readily clarified."

USES A SYSTEMS APPROACH;

Systems Engineering is quite complex, and three types of interdependence are noted: pooled, consequential and reciprocal. Systems Engineering may be defined as the analysis and design of the whole, as distinct from total focus on the components (Ramo and St Clair, 1998). This definition is similar to that of the requirement of dependence for the translation of knowledge across boundaries, in that it is "a condition where two entities must take each other into account if they are to meet their goals" (Carlile, 2004).

In the context of the research conducted, systems engineering may be considered as fulfilled when the result is a detailed description of a specified combination of people and or apparatus, each with their own assignment of function, use of material and pattern of information flow that the whole system presents in order to be compatible, optimal, interconnected, and yielding the desired operating performance (Ramo and St Clair, 1998).

As the reflections of the students do not go into such detail, other considerations should be used such as clarity of goals, objective consideration of alternatives, compromises, trade-offs, and time versus cost requirements. Further project management skills should be described such as relating technology to objectives, available resources and time constraints. Any efforts that are made by "going off in different directions straight away", without first identifying goals and objectives should not be seen as a systems approach, but may be considered if the team re-adjourns to discuss goals. Again, it should be highlighted that if the problem was deemed as easy to understand and the solutions easy to identify, optimize and compare, then the approach should be considered to be the use of common sense and logic, and not Systems Management (Ramo and St Clair, 1998).

Another misguided understanding is that of the "piecemeal approach" – a compromised, chaotic and uncoordinated approach - which should not be construed as a systems approach (Ramo and St Clair, 1998). This approach may not be discernible from the reflections of the students, but rather by the lecturer.

It is important that when coding for a systems approach, that one does not concede that a systems approach was used just because a solution was identified. Any chaotic and disorganised, or indeed, "easy and casual" project that does not conform i.e. meet the criteria of effective communication, should be handled as suspect, and not be considered to meet the criteria of systems approach (Ramo and St Clair, 1998).

It is further noted that difference - or systems approach - cannot be deemed feasible without the incidence of dependence, or communication across disciplinary lines. In instances where a systems approach seems plausible, yet no affirmation of communication across disciplinary boundaries is found, the conclusion of a systems engineering approach should be considered "Not Clear".

Table 3-9: Coding Qualification for Uses a Systems Approach Criteria

Coding	Qualification	Excerpts
No	The student expresses that they did not use a systems approach. Alternatively, the student describes a "piecemeal" approach. The student may identify failure to reach common ground with other students, or identify that the project was completed by them. If the project was deemed as easy to understand and the solutions easy to identify, optimize and compare, then a systems approach was not used.	"I found that we ended up just doing the work separately and then came back and tried to put it all together. This was not a good way of efficiently working through this project. I found 'it easy to engage in strong discussions but others, who didn't seem to have done much in the individual assignment, just sat back and waited to be told what to do"

Not Clear	The student identifies that all team members had an active role, yet do not meet the requirements of communication across a disciplinary boundary and/or effective communication. Reflections that indicate complete chaotic and disorganised development, with no consensus reached should be considered “not clear”, and all reflections indicating an easy and casual project should be handled as suspect, with further elaboration on the systems approach needed from the reflection. . Any efforts that are made by “going off in different directions straight away”, without first identifying goals and objectives should not be seen as a systems approach, but may be considered if the team re-adjourns to discuss goals. Coding is can be completed to identify that it is not clear.	System thinking seems more prevalent in the industrial and information streams. This was not critical. All engineering streams appear to encourage strong reasoning skills; reasoning ability was relied upon to compensate for an actual lack of systems experience.”

Yes	The overall group dynamic moves past the storming phase, and examples of successful efforts around communication barriers are mentioned. Efforts may be technological aids, changing group dynamics and suggestions of resolutions to disputes. Communication across disciplinary boundaries, combined approaches and consensus occurs. Overall reflection should identify with feelings of enlightenment, understanding of new concepts and a practical balanced solution that is representative of most of the disciplines.	"Getting individuals to understand the case from their own perspective and bring together valid discussion points that were similar by content but unique by formulation"

ACQUIRES A WORKING KNOWLEDGE OF CO-WORKERS' DISCIPLINE;

Acquiring a working knowledge of a workers discipline is to be defined as acquiring a fundamental, or rather, rudimentary understanding of another students discipline. As per the Exit Outcomes Level 8 requirement by ECSA, this may be limited to the working knowledge of at least one other discipline of engineering. It is not required that the student is functional in this discipline. A clear distinction should be made between the ECSA Outcomes Level 7, which requires critical awareness of the impact of an engineering activity (Engineering Council of South Africa, 2004).

Table 3-10: Coding Qualification for Acquiring a Working Knowledge of a Co-Workers Discipline Criteria

Coding	Qualification	Excerpts
No	The student expresses that they had not acquired any understanding, knowledge or skill from another discipline.	"Therefore each person would have a chance to be exposed to working in an unknown area, with the aid of someone who has a background in it"
Not Clear	The student expresses interaction with other disciplines and may also identify that as a systems approach, but may not relate to specifics of other disciplines. This is often found in the 'piece-meal" approach. Coding is can be completed to identify that it is not clear	"The group enabled me to draw on the expertise of others, and resulted in a much broader evaluation of the assignment from different perspectives, as opposed to working with likeminded mechanical engineering students. Working in an interdisciplinary group is indispensable for the enhancement of planning efficiency, and it also helped in finding the best solution,"

Yes	The student expresses that they had acquired an understanding, knowledge or skill from another discipline. The student is specific about their newly acquired knowledge or skill, and it is evident that this skill comes from another disciplinary group. This may include new terminology as well.	"I got to learn how to interact with other engineering cultures, terminologies and point of views, as far as engineering is concerned, I learned more from aeronautical side as the cases study we did was technically aeronautical."

3.6 Sampling Techniques

A Sample is a segment of the population selected to represent the population as a whole.

It must be understood that the group of students as and of itself is a sample of systems approach in education. The sample used is non-random due to the fact that the research is limited to the students enrolled for Systems Engineering at the University of the Witwatersrand's Engineering faculties (University of the West of England, 2013). The type of sample will be non-quota probability, which means that the researcher receives feedback from a prescribed number of people (University of the West of England, 2013). Purposive/Judgement sampling has therefore been used for this research project, as the researcher has used a sample based on a pre-defined group (all students enrolled in the course for the year 2011, 2012 and 2013) (Marshall, 1996). The sample size required for qualitative data requires a size of 250, which has been collected (Deming, 1990).

Several students were excluded from the analysis for the following reasons:

- No reflection was found for the student, although their name appeared on the class-list

- Some students did not hand in the required reflection
- Repeating students were identified and had their initial reflection included, but subsequent reflections were excluded as it was not their first experience with cross-dependant studies, although their group is still included as the individual students were experiencing cross-dependant studies for the first time.
- Several students had deregistered from the programme

A total of 470 student reflections (n = 470) were included for the research of this dissertation.

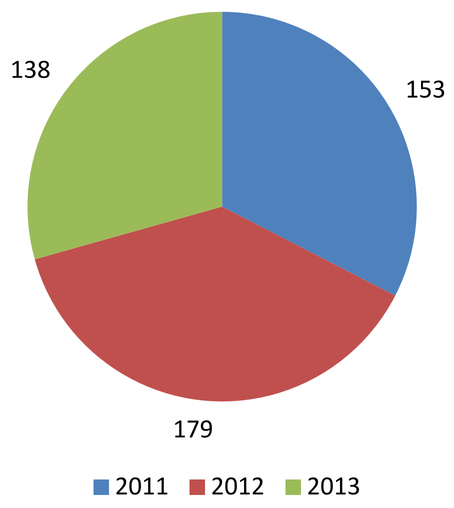


Figure 3-4: Breakdown of Students per Year

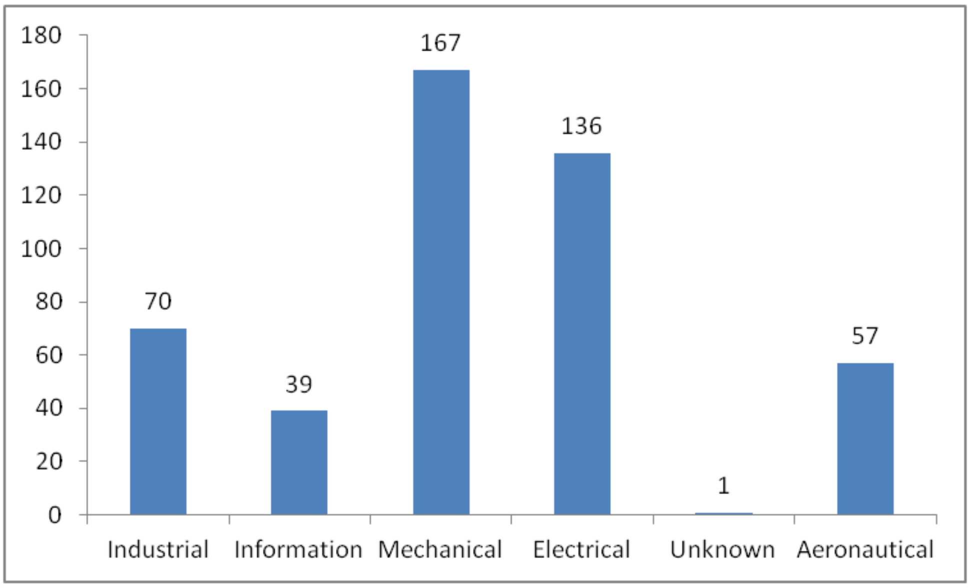


Figure 3-5: Breakdown of Students per Discipline

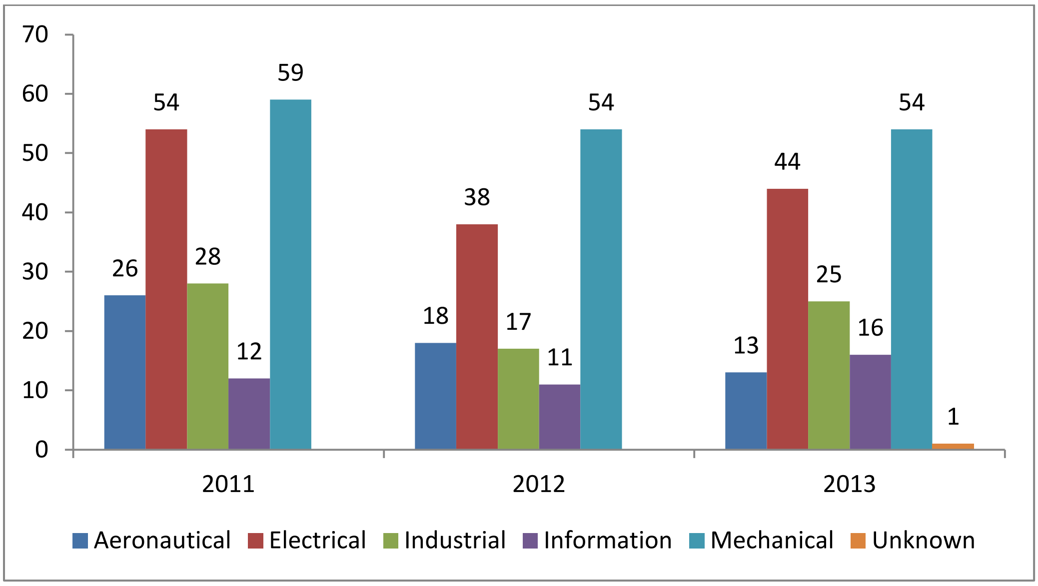


Figure 3-6: Breakdown of Students per Discipline and Year

3.6.1 Calculation of Sample Sizes

Sample sizes were calculated using Cochran's sample size formula (Bartlett, Kotrlik and Higgins, 2001):

$$n = \frac{Z^2\, p(1-p)}{d^2}$$

Equation 1: Cochran's Sample Size Formula

Where:

- n_o is the required sample size,
- t is the a priori α- value of 0.05,
- p the proportionate variable equal to 0.5,
- q the level of acceptable error set to 5%, and
- d is the acceptable margin of error for proportion estimation set to 0.05

If the above calculation yields a value larger than 5% of the total population, Cochran's correction formula is used to create a sample size in response to the actual population.

$$n_1 = \frac{n_0}{(1 + n_0/\text{Population})}$$

Equation 2: Cochran's Correction Formula of Sample Size

Table 3-11: Required Sample Size of Coded Reflections per Discipline

Sampling Measurements	Population Size	Required Sample Size	Percentage of Population Size
Aeronautical	57	49.6	13%
Electrical	136	59.2	56%
Industrial	70	59.2	15%
Information	39	35.4	9%
Mechanical	167	116.4	30%

It is expected that there will be certain instances where there will not be a large enough sample size for some disciplines, as not all reflections will have content to code for each of the ECSA ELO 8 requirement.

Table 3-12: Required Sample Size of Coded Reflections per Year

Sampling Measurements	Year 2011	Year 2012	Year 2013
Population Size	179	138	153
Required Sample Size	122.1	101.53	109.42
Percentage of Population Size	32%	26%	28%

The percentages are more than adequate for further analysis.

3.7 Data Analysis and Interpretation

3.7.1 Inductive Analysis

All qualitative analysis will be completed using Thematic Content Analysis with NVivo software and verified using Pearson's Correlation. The emergent themes will then be used to understand the outcomes of deductive analysis and explored using extant literature.

3.7.2 Deductive Analysis

Qualitative analysis pertaining to hypotheses suggested will be completed after qualitative analysis using Minitab software. As the researcher is focused on the overall requirement of the ELO 8 being met, the most important considerations in assessing results are not those relating to statistical sampling variation, but those which appraise the following factors and their effects (Statistical Services Centre, 2001):

1. The evenness of coverage of the target (intended) population
2. The suitability of the sampling scheme reviewed in the light of field experience and findings
3. A sophistication and uniformity of response elicitation and accuracy of field recording

4. The efficacy of measures to prevent, compensate for, and understand non-response
5. The quality of data entry, cleaning and metadata recording
6. The selection of appropriate subgroups in analysis

For the above considerations, any categorical or ELO 8 requirements that have uneven effects will introduce biases, of which the size and detectability will be appraised and reported with the conclusions.

Inference And Maximum Likelihood

Inference addresses issues such as whether apparent patterns in the results have come about by chance or can reasonably be taken to reflect real features of the population (Statistical Services Centre 2001). Inferential statistical procedures will be used to create generalisations from the sample to the population, where the results are not adversely affected by any of the effects listed above (Statistical Services Centre 2001).

There are many approaches to calculating the inference of a population, from point estimation to maximum likelihood. The Clopper-Pearson "exact" confidence interval for $\hat{p}$ may be used to calculate an approximation for the student population and is considered the "gold standard" by many. It has been found to be very conservative and inappropriate for statistical practice by some statisticians, as the actual coverage probability can be much larger than the nominal confidence level unless n is quite large (Agresti and Coull, 1998). The Clopper-Pearson interval has coverage probabilities bounded below by the nominal confidence level, but the typical coverage probability is much higher than that level.

Other methods of calculating a confidence interval may be used. The score and adjusted Wald can have coverage probabilities lower than the nominal confidence level, yet the typical coverage probability is close to that level.

In forming a 95% confidence interval, is it better to use an approach that guarantees that the actual coverage probabilities are at least 0.95, but will typically achieves coverage probabilities of about 0.98 or 0.99. The score and adjusted Wald confidence intervals for p provide shorter intervals with actual coverage probability, usually nearer the nominal confidence level. (Agresti and Coull, 1998)

Traditionally, a point estimate is calculated using the Wald Confidence Interval, and is based on the asymptotic normality of the sample proportion and the estimation of the sample error. If X is the binomial variant for a sample size *n*, the proportion of the sample is denoted as $\hat{p}$ and is equal to X/*n* (Agresti and Coull, 1998). Thus, the 100(1-α) confidence interval is calculated using the following equation:

$$\hat{p} \pm z_{\alpha/2}\sqrt{(\hat{p}\,(1-\hat{p})/n}$$

Equation 3: Wald Confidence Interval *(Agresti and Coull, 1998)*

where *zc* denotes the 1-c quartile of the standard normal distribution, and the interval is the set of p values having *p* value exceeding *a* in testing $Ho : \hat{p} = po$ against $Ha: \hat{p} \neq po$ using the test statistic:

$$z = (\hat{p} - p_0)/\sqrt{\hat{p}\,(1-\hat{p})/n}$$

Equation 4: Test Statistic for Z *(Agresti and Coull, 1998)*

The Wald test does not perform well on small sample sizes, and has several assumptions that need to be met before it can be considered (Agresti and Coull, 1998).

A score confidence interval is seen as optimal as the score tests, and in particular their standard errors, are based on the log likelihood at the null hypothesis value of the parameter, whereas Wald tests are based on the log likelihood at the maximum likelihood estimate.

A score interval is calculated using the following equation (Agresti and Coull, 1998):

$$(\hat{p} + \frac{z^2_{\alpha/2}}{2n} \pm z_{\alpha/2} \sqrt{\hat{p}\,(1-\hat{p}\,) + z^2_{\alpha/2}\ /4n\,)\,/\,(\,1 + z^2_{\alpha/2}\ /\,n)}$$

Equation 5: Score Interval *(Agresti and Coull, 1998)*

Inference will be calculated using a point estimate for the “Not Clear” coded reflections, so as to infer whether each ELO 8 requirement could potentially have been met. Inference for the student population will be calculated using Wald’s Adjusted Confidence interval as well as a score interval.

Interpretation of the confidence interval is to be considered definitive in that the actual coverage probability of an interval estimator is the (a priori) probability that the interval contains that value. In other words, the confidence coefficient is defined to be the minimum of such coverage probabilities for all possible values of that parameter, and it should be understood that the interpretation should be considered the average reflection of the student meeting the ELO 8 requirements, and not a worst case scenario (Agresti and Coull, 1998).

MULTIPLE RESPONSE DATA

Due to the nature of the coding used, the data is considered "multiple dichotomy”, as there is a yes/no response in each coding of the ECSA ELO 8 outcomes. Profiling will be used in conjunction with analysis, as the researcher seeks an overall view of individual responses. Profiling may be understood as the description synthesising the students reflections to the range of questions (Statistical Services Centre 2001). It may describe an individual, cluster of respondents or an entire population. The decision to use profiling was considered after data collection and during analysis.

This is considered as common-place, and improves the rigour of the research, as expected in fieldwork approaches allow for new ideas to come forward (Statistical Services Centre 2001). For this reason, cross-tabulations of individual questions are not a sensible approach to “people-centred‟ or “holistic‟ summary of results (Statistical Services Centre 2001).

Profiling will be done by the derivation of a synthetic variable, also known as an indicator, which will summate the outputs of each student so as to describe the 'compliance" of the student to the ELO 8 requirements. Two sets of profile will be created for each student, and will therefore comprise of a set of values of a suite of indicators, as follows:

DICHOTOMOUS PROFILING

Each coded requirement met is scored as "Yes", with each requirement coded as not met, "No". A tally of each is then calculated, and used as a dichotomous scale for analysis.

Each requirement is assigned a value, whereby meeting the requirement i.e. "Yes" is allocated a value of 1. Each negative response ("No") is allocated a value of -1, and any ambiguous or contradictory reflection ("Not Clear") is allocated a value of 0, so as to ensure that it is considered neutral and does not affect the overall score of the student. After each requirement is coded in this way, an overall score per student is found, indicating the level at which they had met the requirements. It is noted that the nominal profile is considered more stringent, as students are "penalised" for any requirements not met.

NOMINAL PROFILING OF OUTCOMES

Each requirement is assigned a value, whereby meeting the requirement i.e. "Yes" is allocated a value of 1. Each negative response ("No") is allocated a value of -1, and any ambiguous or contradictory reflection ("Not Clear") is allocated a value of 0, so as to ensure that it is considered neutral and does not affect the overall score of the student. After each requirement is coded in this way, an overall score per student is found, indicating the level at which they had met the requirements. It is noted that the nominal profile is considered more stringent, as students are "penalised" for any requirements not met. The % of ECSA Outcomes Met is calculated by dividing value of the value allocated by the amount of criteria (Value of 9).

Table 3-13: Dichotomous Score of Outcomes

ECSA ELO Requirement	Student 1	Value Allocated	Student 2	Value Allocated	Student 3	Value Allocated
Benefits From Support of Team Members	Not Clear	0	Yes	1	Yes	1
Communicates Effectively with Team Members	Not Clear	0	Yes	1	Not Clear	0
Delivers Completed Work on Time	Not Clear	0	Yes	1	Yes	1
Enhances Work of Team Fellow Members	Yes	1	Yes	1	Not Clear	0
Makes Individual Contribution to Team Activity	Not Clear	0	Yes	1	Yes	1
Performs Critical Functions	Not Clear	0	Yes	1	Not Clear	0
Acquires a Working Knowledge of Co-Workers Discipline	Yes	1	Not Clear	0	No	-1
Communicates Across Disciplinary Boundaries	Yes	1	Yes	1	No	-1
Uses Systems Approach	Yes	1	Yes	1	Not Clear	0
Total ELO 8 Outcomes Met ("Yes")	4		8		3	

Total ELO 8 Outcomes Not Met ("No")	0	0	-2
Total ELO 8 Met From Criteria of Nine	4	8	1
% of ECSA Outcomes Met	44%	89%	11%

Table 3-14: Example of Scaled Responses for Team Work

ECSA ELO 8 Requirement	Student 1	Value Allocated	Student 2	Values Allocated	Student 3	Values Allocated
Benefits From Support of Team Members	Not Clear	0	Yes	1	Yes	1
Communicates Effectively With Team Members	Not Clear	0	Yes	1	Not Clear	0
Delivers Completed Work on Time	Not Clear	0	Yes	1	Yes	1
Enhances Work of Fellow Team Members	Yes	1	Yes	1	Not Clear	0
Makes Individual Contribution to Team Activity	Not Clear	0	Yes	1	Yes	1
Performs Critical Functions	Not Clear	0	Yes	1	Not Clear	0
Acquires a Working Knowledge of	Yes	1	Not Clear	0	No	-1

Co-Worker's Discipline						
Communicates Across Disciplinary Boundaries	Yes	1	Yes	1	No	-1
Uses a Systems Approach	Yes	1	Yes	1	Not Clear	0
Effective Team Work Total	1		6		3	
Multi-disciplinary Work Total	3		2		-2	
Total ECSA Outcomes Level 8	4		8		1	
% Effective Teamwork Met	17%		100%		50%	
% Multi-disciplinary Work Met	100%		67%		-67%	

In Table 3-14, the data is scrutinized further by stratifying into Team Work and Multidisciplinary Work.

The first six criteria are considered Team Work, whereas the remainder are considered Multidisciplinary Work. When considering the overall evaluations in Table 3-15, it shows that there may be a disproportionate amount of students that focus on different areas.

Table 3-15: Comparison of Effective Teamwork and Multidisciplinary Work

ECSA ELO 8 Requirement	Student 1 Value Allocated	Student 2 Values Allocated	Student 3 Values Allocated
Effective Team Work Total	1	6	3
Multidisciplinary Work Total	3	2	-2
Total ECSA Outcomes Level 8	4	8	1
% Effective Teamwork Met	17%	100%	50%
%Multidisciplinary Work Met	100%	67%	-67%
% of ECSA Outcomes Met	44%	89%	11%

The % of ECSA Outcomes Met will therefore be used as the validation indicator when analysing the data, and will be used as a secondary profile for each student.

COMPARING PROFILES - VALIDITY

The indicators are therefore well-understood and validated, and synthesise information and serve to represent a reasonable measure of the reflections of students in terms of the ECSA ELO 8 requirements for the course MECN4020. The indicators also meet the requirements of a priori, as outlined earlier. (Statistical Services Centre 2001).

The combination of these methods may all be encompassed in triangulation. By using the results of different approaches to synthesise robust, clear, and easily interpreted results. This allows for Content Validity, as it looks at the extent to which the ELO 8 requirements are met by using the dichotomous scale and validation by the nominal scale. Results are weighed by both indicators, and therefore serves to cover the important sub-requirements of the ELO 8 requirements that are represented by the indicators ECSA Outcomes "Yes", ECSA Outcomes “No” and “% of ECSA Outcomes Met” (Statistical Services Centre 2001).

TRIANGULATION

'Triangulation' is a process of verification that increases validity by incorporating several viewpoints as well as methods (Yeasmin and Rahman, 2012). The purpose of triangulation is to obtain confirmation of findings through convergence of different perspectives.

Standard n the science and engineering field, the findings of a researcher are held to have been validated when another researcher in a separate setting is able to repeat the original experiment with identical conclusions (Yeasmin and Rahman, 2012). However, this form of validation by replication is not possible where the field of research takes concerns particular and unique features that cannot be exactly reproduced in a second setting, or even in the same setting.

This is of particular importance to this study as it refers to the combination of two or more theories, data sources and methods or in one study of a single phenomenon to converge on a single conclusion. It utilises both quantitative and qualitative methods and is known as methodological triangulation - using more than one research method (Yeasmin and Rahman, 2012). It is imperative to note that triangulation is not merely aimed at validation in isolation, but at deepening and widening one's understanding.

The validity of the analysis is improved as there are no major discrepancies of understanding the coding criteria and coding of themes, processes of comparison and reflection and redevelopment of definitions, approaches and research instruments if required.

LOGISTICAL MODELLING

Due to the complexity of the data - multiple levels and unequal numbers at each subdivision of the data -inferential methods will include log-linear and logistic models (multilevel modelling). Log-linear and logistical modelling, known as canonical link functions, are favoured over other methods as parameter estimates under logistic regression are fully efficient, and tests on those parameters are better behaved for small samples, which is considered pivotal due to the large variation in sample sizes across disciplines (Simonoff, 2012). It also allows for analysis regardless of prospective or retrospective sampling, as its cross-product ratio is unambiguous.

As the study is retrospective, the probabilities of "Yes" and "No" have been coded for a subset of students in a multidisciplinary study. It is considered the base rate of the research. The probability for this sub-set can be adjusted for the entire population, so that probability of each requirement being met can be estimated. This adjustment is only allowed for retrospective probability. Binomial logistic analysis will be used initially, but may not be suitable if there is correlation among the categorical factors (or predictors), or alternatively if there is heterogeneity in the success probabilities that has not been modelled. Both of these violations can lead to over-dispersion, where the variability of the probability estimates is larger than would be implied by a binomial random variable (Simonoff, 2012). Nominal Logistic Regression will be used in these instances.

INTERPRETATION OF BINARY MODEL OUTPUTS

Guidelines to be followed during interpretation will include

- Extremely high values for parameter and for standard errors indicate that the number of explanatory variables is too large relative to the number of subjects. The research requires that the increase of number of subjects or removal of one or more explanatory variables from the analysis. (Health *et al.*, 2013)
- Logistic regression is sensitive to co-linearity among the explanatory variables. The symptom of co-linearity is high values for standard errors in parameter estimates. (Health *et al.*, 2013)

3.8 Ethical Considerations

3.8.1 INFORMED CONSENT

No names or student numbers were used, so the identity of any individual student was protected and completely confidential.

4 ANALYSIS AND RESULTS

This chapter presents the thematic analysis of the student reflections through which firstly, emergent themes were identified and secondly, the hypotheses were explored. For each of these two analyses, the methodological qualitative approach is first explained followed by the presentation of the results.

4.1 Data Processing

This section explains how the data (students' reflections) was processed in NVivo so as to conduct coding to identify the emergent themes.

All students that were repeating the course were identified. Their first reflection was included in the analysis, but all subsequent reflections were excluded. All reflections of students were retyped so that no demarcations from the lecturer could be seen, so as to avoid any bias. A spell-check was run, although the grammar used by the students was not changed. This allowed for "verbatim" reflection of students, without jeopardising the emergence of themes from NVivo, which is highly sensitive to spelling.

The reflections were cross- referenced to student numbers on a class-list and categorical data was updated. The completed reflections (in the form of Microsoft Word documents) is imported into NVivo. Nodes were created for every student so that each could be classified in regard to:

- Year of study
- Group
- Branch of engineering
- Mark attained
- School of engineering
- Number of group members
- Gender
- Race

Certain biographical data could not be allocated and "Unknown" was assigned to those students (as shown in Figure 4-1).

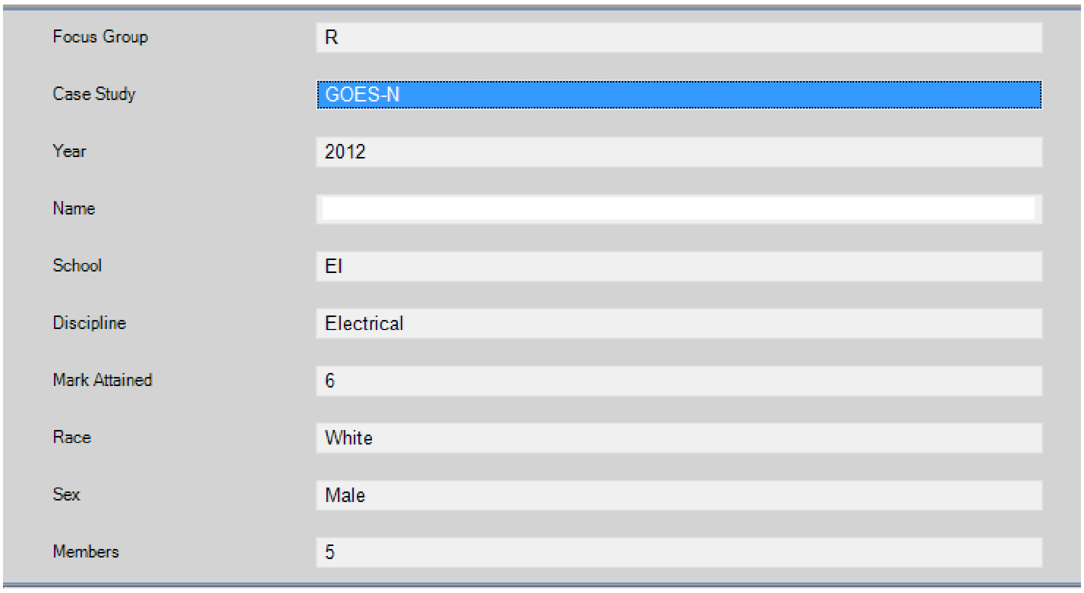


Figure 4-1: Example of Assigned Categorical Data

Several queries were run on NVivo. The first query run was a word frequency query. The parameters for the query were set as follows:

The query was limited to the fifty most repeated words, with a minimum length of five characters, so that articles and pronouns would be excluded (see Figure 4-2 for NVivo settings).

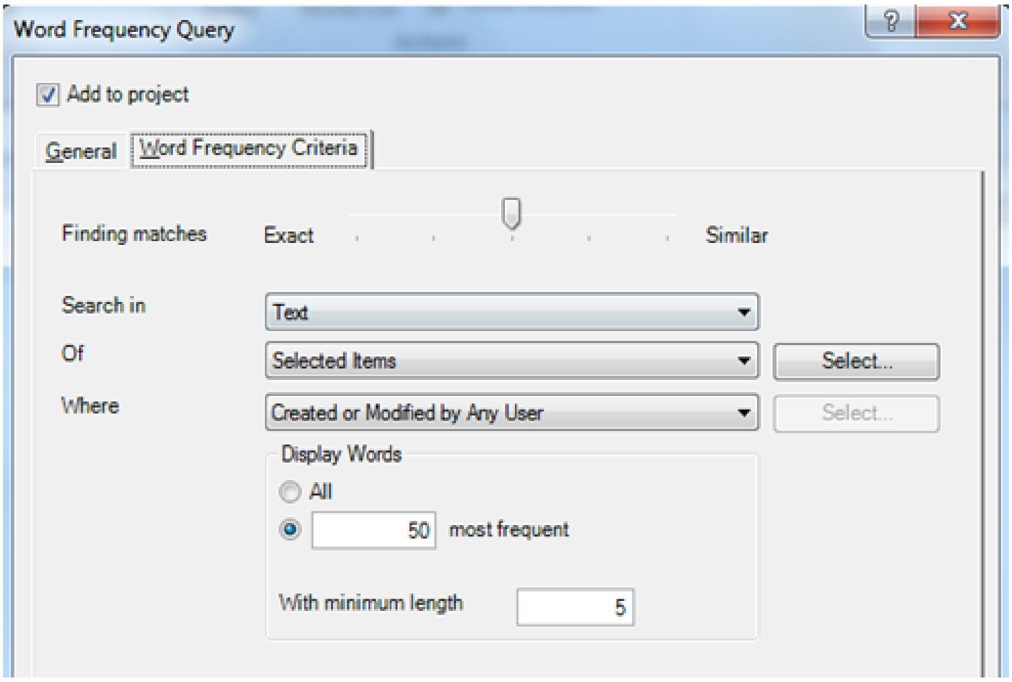


Figure 4-2: NVivo Settings

Synonyms were not matched, as NVivo groups certain words together by default. This is shown in Table 4-1, where, for example, similar words for “differ” are “differed”, “difference”, “differences”, “different” etc. A list of 95% weighting of words may be found in Appendix D.

Table 4-1: Default Setting of Synonyms

Word	Length	Count	Weighted Percentage [%]	Cumulated Weight Percentage [%]	Similar Words
Differs	7	1639	8%	16%	differ, differed, difference, differences, different, differently

Project	7	1520	8%	24%	project, projects
Members	7	1500	8%	31%	member, members, members', members’
Engineers	9	1354	7%	38%	engine, engineer, engineered, engineering, engineers, engineers', engineers’
Working	7	1153	6%	44%	worked, working, workings
Meetings	8	775	4%	48%	meeting, meetings
Students	8	713	4%	52%	student, students, students', students’
Problems	8	702	4%	55%	problem, problems
disciplines	11	586	3%	58%	discipline, disciplined, disciplines, disciplines’
experience	10	533	3%	61%	experience, experiences, experiments

It is clear from the word query that differs (and all the aligned stemmed words - differ, differed, difference, differences, different, differently, differing, differs - alludes to specific challenges that the students faced. Project management is seen as a large part of the total reflection, which had previously been identified in a pilot study (Sunjka, 2011c). Almost all words allude to some type of conflict.

The word query, although helpful in understanding the emergence of terminology frequently used, does not identify the correlation between the terms per se.

A word cluster enquiry is run to show a strong correlation between coded themes and words. Only terms with a strong correlation are shown together. The researcher also has insights from the actual coding as to how the correlations could be drawn.

It is expected that conflict is to emerge from several sources:

- Group formation - forming, storming, norming and performing of across several categories
- Literature Review information, including external and internal courses offered in multidisciplinary studies
- Findings of pilot studies
- Actual reading and coding of the data (student reflections)

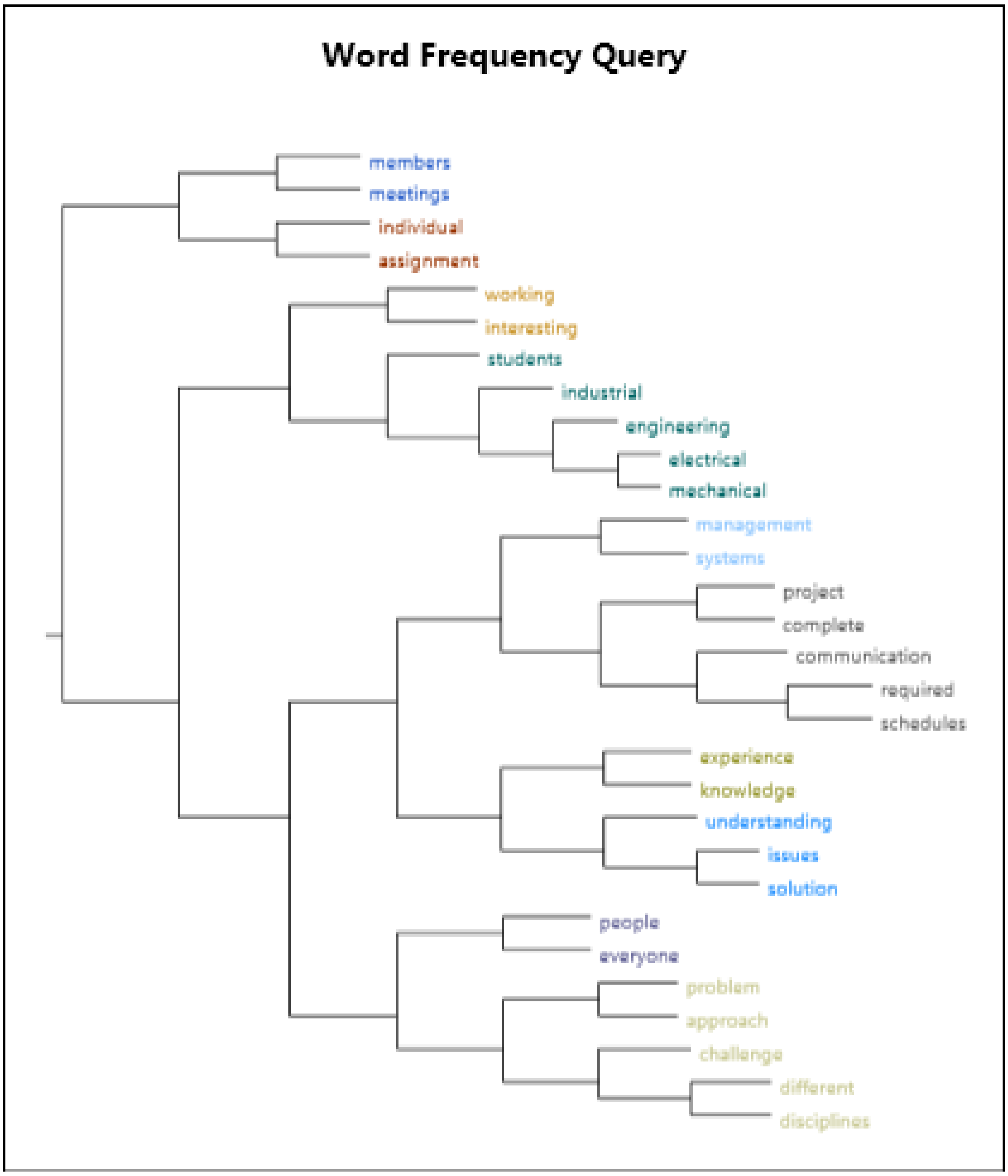


Figure 4-3: General Word Query of Emergent Themes of Total Sample

A general word query generated provided the grouping of words based on the coding completed (Figure 4-3). A close proximity to the left of the word frequency indicates the level of correlation. Combining the correlation with the expected emergent themes, the following branches have high correlation:

- Conflicts
- Difference between discipline types
- Project Management

4.2 High Level Results

4.2.1 Conflicts

A query for conflict is run in NVivo Conflict between individuals, highly correlated with assignments and meetings suggest timetable clashes, which would occur across every discipline and indeed between the Schools of MIA and EI respectively.

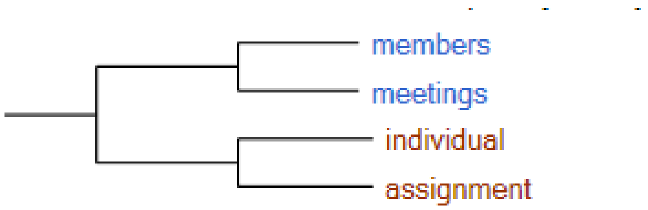


Figure 4-4: Emergent Theme Conflict

Coding will consider both general comparisons, where schools are not mentioned, but differences are apparent due to timetable clashes, as well as specific mention of the differences experienced between the two schools of engineering.

Any mention of timetable clashes, individuals with assignments to complete and/or members that cannot attend meetings, with reasons given for not attending meetings will be coded. Particular mention, whether generalised or attributed specifically to a school will therefore be coded as identified by the emergent themes:

- General conflict
- Conflict Mentioning MIA
- Conflict Mentioning EI

4.2.2 Differences Between Disciplines

The correlation between the terms working and interesting and the strong correlation with students and their disciplines indicates the students reflect the working with students from different disciplines (Figure 4-5).

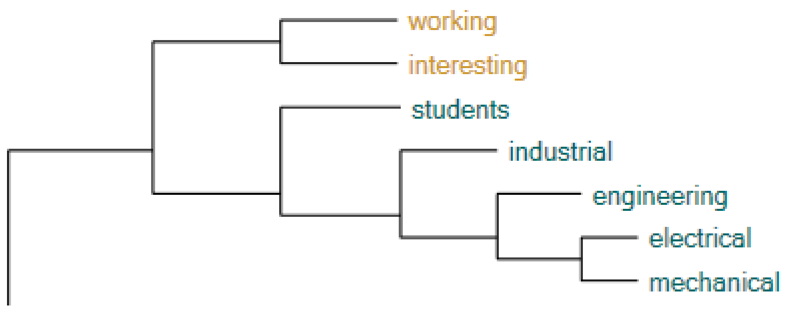


Figure 4-5: Emergent Theme Conflict between Disciplines

The core competencies or work complete by a particular individual will be coded to ascertain what other disciplines identified as critical tasks performed by a particular discipline. The codes are built by the researcher and not the software, NVivo.

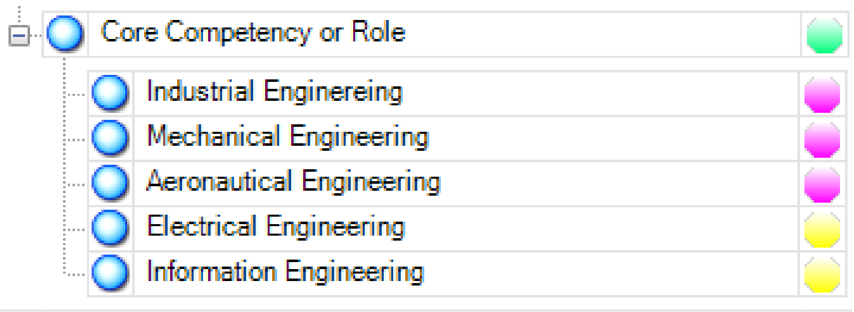


Figure 4-6: Nodes Indicating Core Competencies of Each Discipline

Any opinions given by students – that is, any reflection of a discipline that is not substantiated by the student with a particular task or core competency completed – will be coded as the opinion given rather than a core competency. Dimensions can be developed using the "flip-flop" technique, whereby one would compare extremes on one dimension. This assists the researcher in thinking analytically rather than descriptively e.g. comparing young against old (Bryman and Gibbs, 2008). The "flip-flop" technique is used for the dimensioning of discipline differences, and coding shall consider both positive and negative aspects.

Coding will include:

- Positive/neutral commentary -any positive or neutral comments made by a student on another discipline or individual from a particular discipline, including concepts that were found to be interesting.
- Negative commentary - any criticism that is made by a student on another discipline or individual from a particular discipline

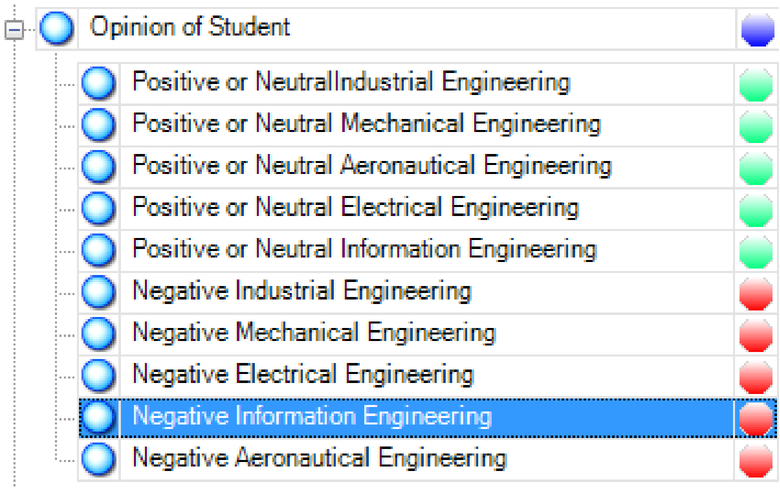


Figure 4-7: Nodes Created for the Negative and Positive Opinions of Other Disciplines

All coding will be analysed further to identify specific causal and central phenomenon that would indicate the correlation between different disciplines, their core competencies and their opinions of other disciplines.

4.2.3 Project Management

A query is run for coding of Project Management. The reflections of the students indicate the clash of schedules, effective communication and project progress, all of which may fall under the coding of project management (Figure 4-8).

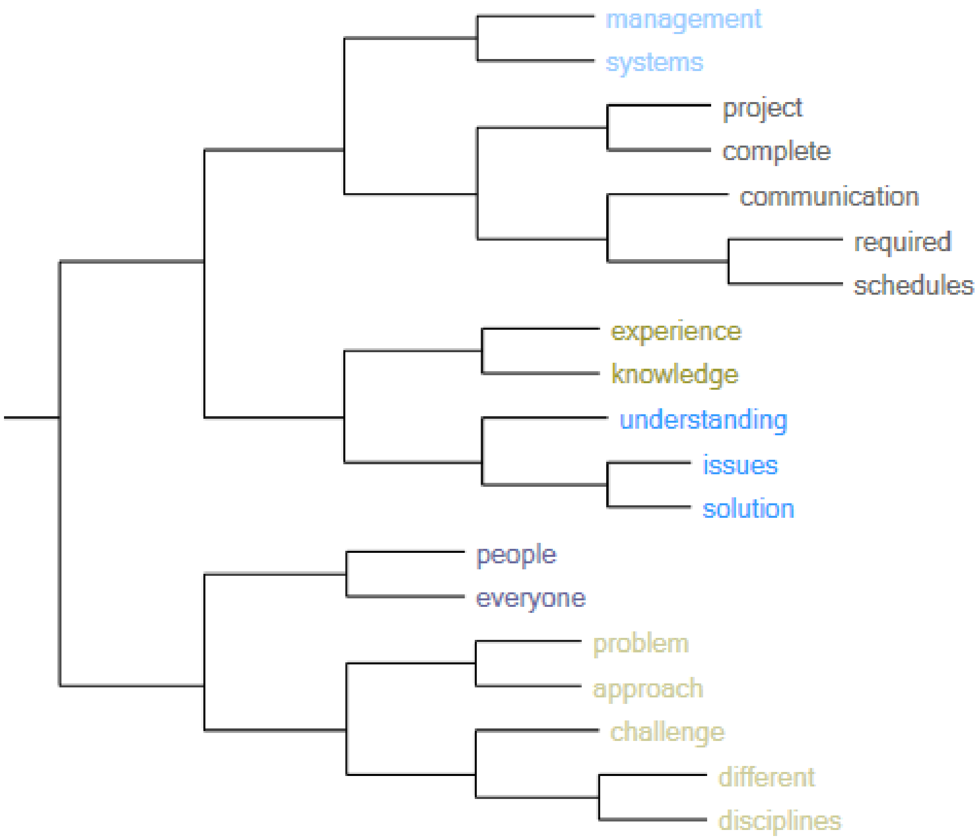


Figure 4-8: Cluster of Conflict: Schedules, Communication and Progress

The first cluster indicates the correlation of schedules and requirements, correlating quite highly with communication, separate from but equal to project and completion, with the total sub-cluster mentioned above equal, yet separate from management and systems.

The second cluster indicates the correlation of experience and knowledge, equal but separate to the theme of understanding, which in turn is strongly correlated with issues and solution. The overall theme of communicating across a disciplinary boundary is strongly suggested.

The next cluster, linked closely to communicating across a disciplinary boundary but isolated in terms of its particular correlation of terms, includes a role player (people, everyone), clash (problem, approach), challenge, and a strong relation to different and disciplines. Identified as the basic requirements for group formation, this cluster alludes to the forming, storming, norming and performing of students, and is highly correlated to effective communication, as outlined in the Literature

Survey. The use of effective communication as well as communicating across a disciplinary boundary is required to move past the storming phase of group formation dynamics. The coding for these emergent themes will be deemed as communicating across a disciplinary boundary and effective communication. Emergent themes are identified as:

- Management
- Communication
- People Management
- Experience

All coding completed for both ECSA requirements will be analysed further to identify specific causal and central phenomenon that has allowed the student to communicate effectively as well as communicate across a disciplinary boundary.

4.2.4 DISCOURSE

Although not emergent, discourse analysis will be used by the researcher to identify themes that are seldom reflected on expressively, but may appear as an anomaly or once-off in the reflections. They are coded as they are discovered in vivo. This type of coding is the practice of assigning a label to a section of data (the reflection), using a word or short phrase taken from that section of the data (King, 2014). The reflections are later recoded to identify any other examples of these occurrences.

4.3 Exploration of Conflict

A word frequency query is run for the node being explored, with all stemmed words (e.g. work, working, worked) with a length of at least five characters found. Within the list of words found, all nouns are then each allocated as child nodes to a new parent coded as "reflections of". Cluster analysis is run and identifies emergent themes, correlation and a Pearson's Coefficient per emergent theme.

4.3.1 General Conflicts

General conflicts are coded where students identified conflict areas, but did not indicate a specific school, but rather a general conflict that occurred that involved the individual as shown in Figure 4-9.

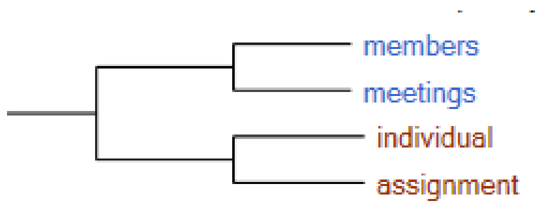


Figure 4-9: Cluster of General Conflict

A word frequency query was run for the node where general conflicts were coded, with all stemmed words (e.g. work, working, worked) with a length of at least five characters is found. The list of words is then each allocated as child nodes to a new parent node "Reflections of General Conflicts". Cluster analysis was run with the following results as shown in Figure 4-10:

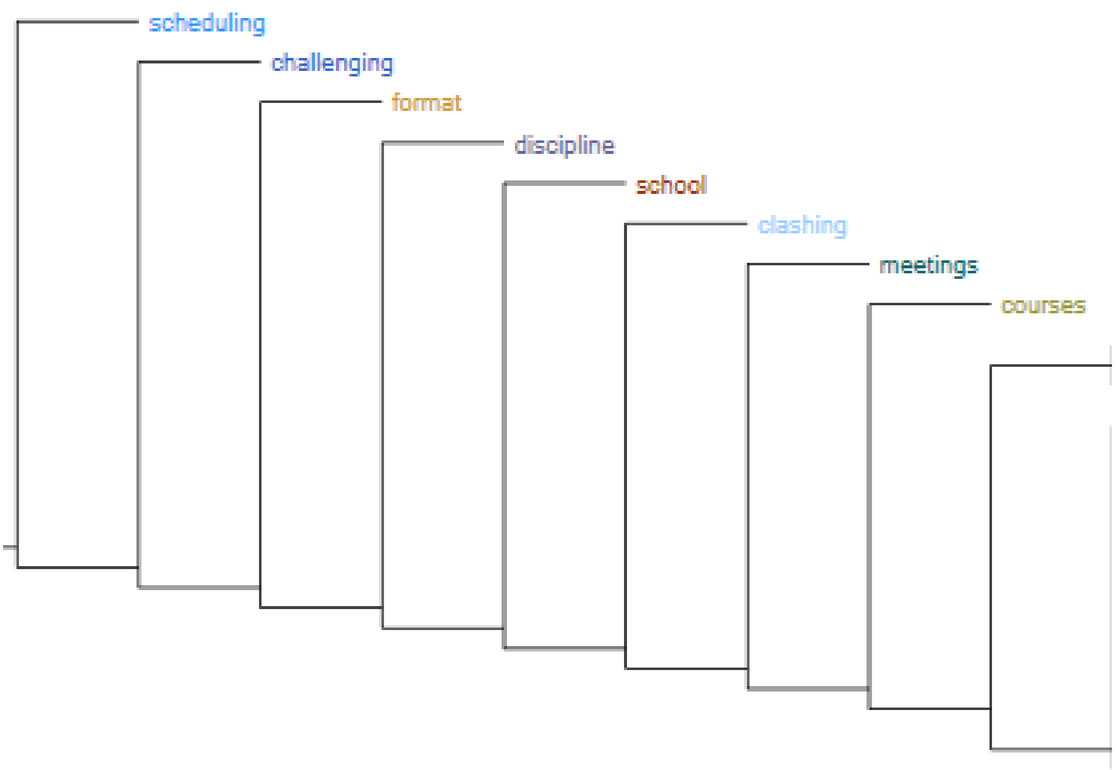


Figure 4-10: Emergent Cluster of General Conflict

Figure 4-10 included scheduling, format, discipline, school, clashing, meetings and courses. Starting from the left, it is shown that scheduling was the main conflict, which was described as challenging. This strongly correlated with the following themes:

- Schedule
- Management
- Resolution
- Approach
- Group Formation
- Effective Communication

4.3.2 CONFLICTS MENTIONING MIA

A word frequency query was run for the node where conflicts mentioning MIA is coded, with all stemmed words (e.g. work, working, worked) with a length of at least five characters was found. The list of words is then each allocated as child nodes to a new parent node “Reflections of Conflict MIA”. Cluster analysis was run, and yielded the following results:

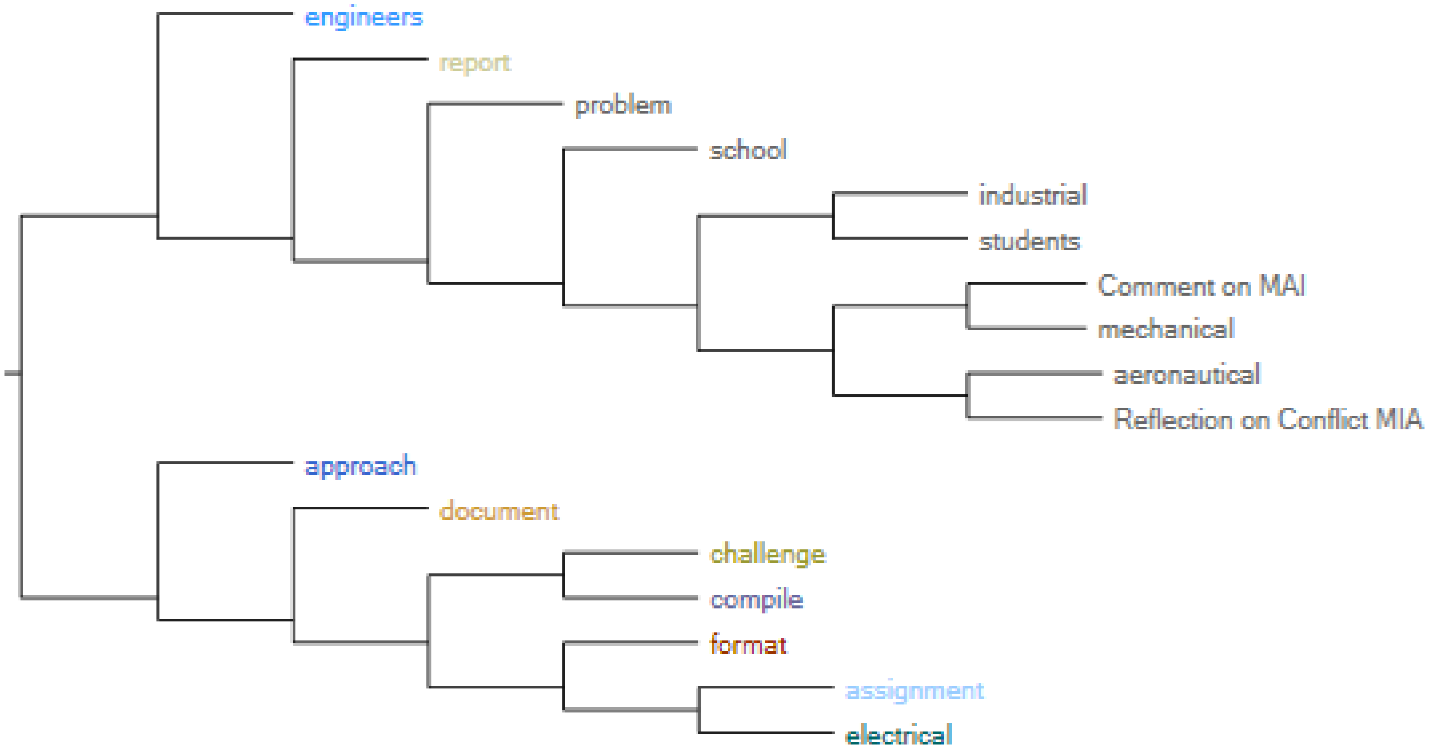


Figure 4-11: Emergent Cluster of Conflict with MIA

There is a binomial emergence of conflict areas. The first cluster identifies the report as an issue, and then correlates strongly with industrial engineers separate from mechanical and aeronautical students. The second cluster isolates the electrical engineer from the other disciplines, and correlates with both approach and document using words like challenge, compile and format.

The emergent themes to be identified are those of the report writing styles being considered problematic by the MIA students when compared to the EI students in terms of compiling and formatting documents, approach, and reports. It is also evident that the electrical engineer is seen as completely separate from the MIA students in this regard.

Emergent themes are identified as:

- Split between Schools in Format and Compilation of Document
- Separation of Electrical Engineers

4.3.3 Conflicts Mentioning EI

A word frequency query was run for the node where conflicts mentioning EI were coded, with all stemmed words (e.g. work, working, worked) with a length of at least six characters was found. The list of words is then each allocated as child nodes to a new parent node “Reflections of Conflict EI”. Cluster analysis was run, and yielded the following:

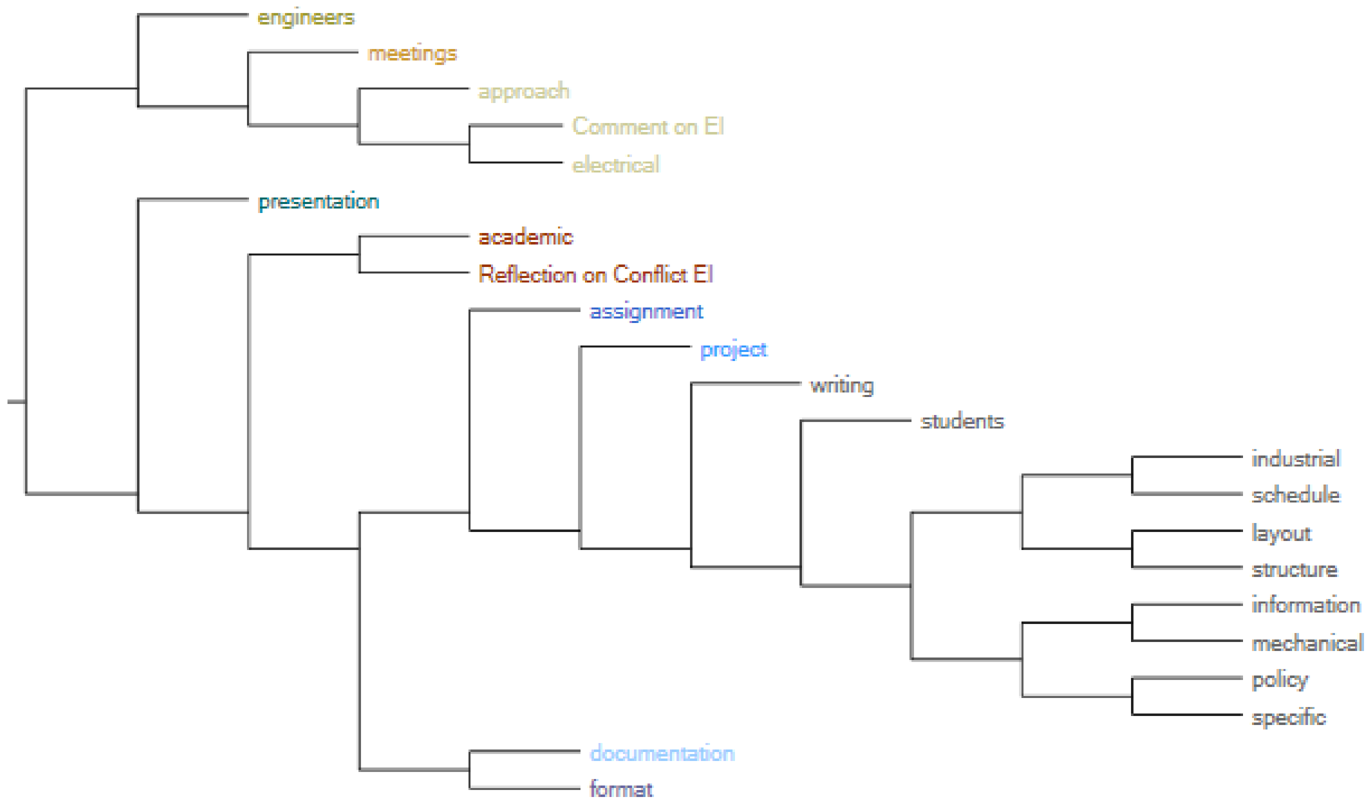


Figure 4-12: Emergent Clusters of Conflict with EI

The first cluster indicates the distinct view of students that the electrical engineers have a different approach to other engineers. It is also noted that meetings are considered as difficult to arrange.

The second cluster indicates that the presentation was problematic. Presentation is an ambiguous term as it may allude to the actual presentation required in 2011, or may be concerned with the overall presentation of the report. As the presentation was only required in 2011, it is assumed that the conflict between the Electrical Engineer and other engineers was heightened when a presentation was required. A compounded search in NVivo identified that the term "academic" was often used within the same context as "abstract" or "particular" in relation to the Electrical Engineering student.

As with the emergent themes from "Conflicts with MIA", the above cluster (Figure 20) is similar in that there is a distinct divide between Electrical Engineers and the Mechanical, Aeronautical and Industrial engineers, pertaining to both their approach and report writing. An excerpt taken from one student clearly identifies this:

> *"The clashes were mainly due to the different terminologies and the layout of the project. The school of electrical engineering has a specific layout (as per the blue book) for the presentation and layout of projects. The electrical engineers in the group are accustomed to these rules, as they have been abiding to them for four years"*

It is surprising to see the inclusion of Information Engineers within the second cluster, separate from the Electrical Engineers. As this inclusion falls under the cluster identified by "presentation", it is assumed that the Information Engineers are able to adapt to the other engineers' format for the presentation itself, and/or with the report writing style of the MIA student.

Emergent themes identified include:

- Separation of Electrical Engineers
- Difference in Presentation between the School of MIA and the School of EI

- The Abstract Approach of the School of EI

4.4 Differences Between Disciplines

4.4.1 Student Reflections on Core Competencies of Different Branches

The core competencies or work complete by a particular individual will be coded to ascertain what other disciplines identified as critical tasks performed by a particular discipline.

Aeronautical Engineering

A word cluster was created for the core competencies of the Aeronautical Engineer and returned the following result:

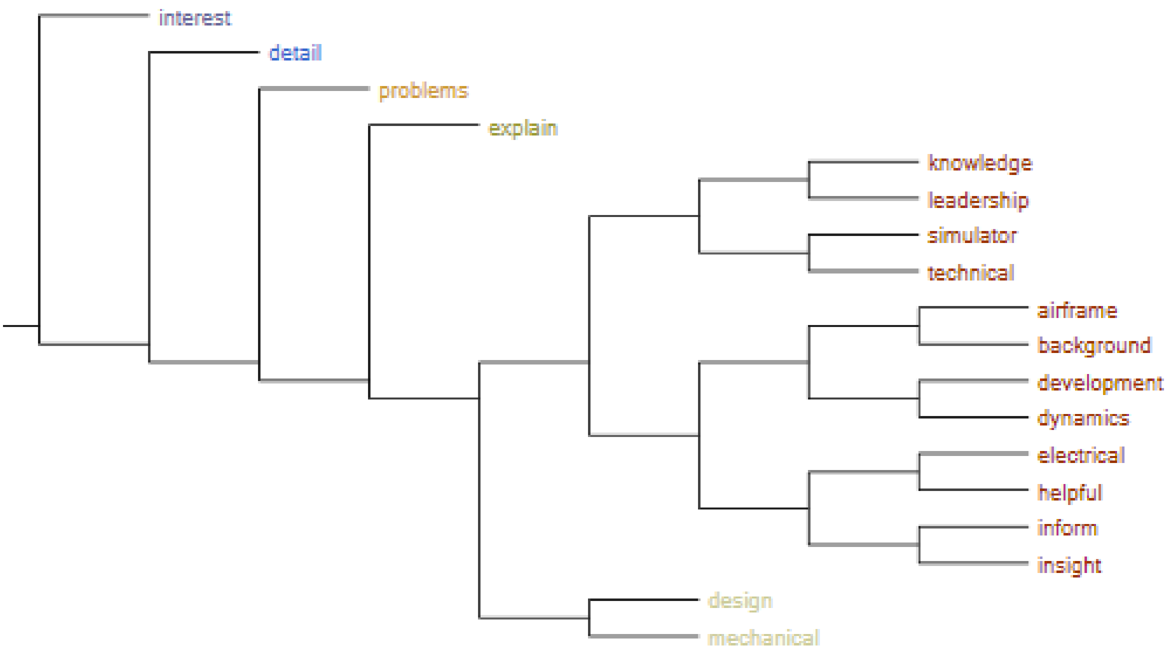


Figure 4-13: Core Competencies of Aeronautical Engineering

Emergent core competency of the Aeronautical Engineer seems to be that of relaying details and explaining technical aspects of the problem – simulator, background, dynamics, inform, insight. They seem to share an interest in the design aspect along with the Mechanical Engineers. Leadership is noted but is not seen as a core competency; rather it would seem that the Aeronautical Engineer takes the leadership role when technical details are needed.

Core competencies of Aeronautical Engineers are identified as:

- Explaining Technical Aspects
- Design Driven
- Leadership in Technical Aspects

Electrical Engineering

A word cluster was created for the core competencies of the Electrical Engineer and returned the following result:

The emergent core competency of the Electrical Engineer is two-fold. The first theme (Figure 4-14) is that of detailed assistance in both analysis and software.

The second emergent theme is that of leadership, displayed during calculations and programming, which is expected by other students. It also shows that other students find the Electrical Engineer useful and helpful with perspective; control, the report; information and understanding; presumably from an Electrical discipline perspective.

The emergent themes for the core competencies of Electrical Engineers are identified as: Detailed Assistance in Software, Leadership in Calculation and Programming.

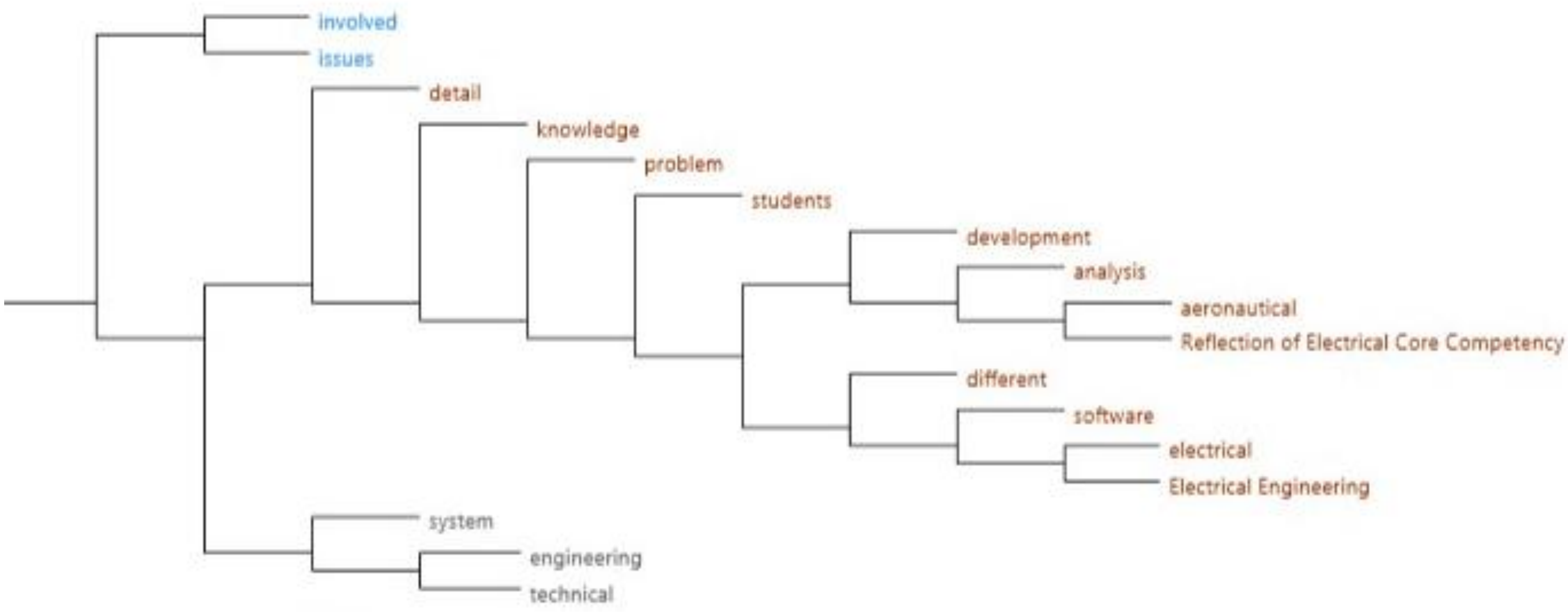


Figure 4-14: Core Competency of Electrical Engineering Cluster 1

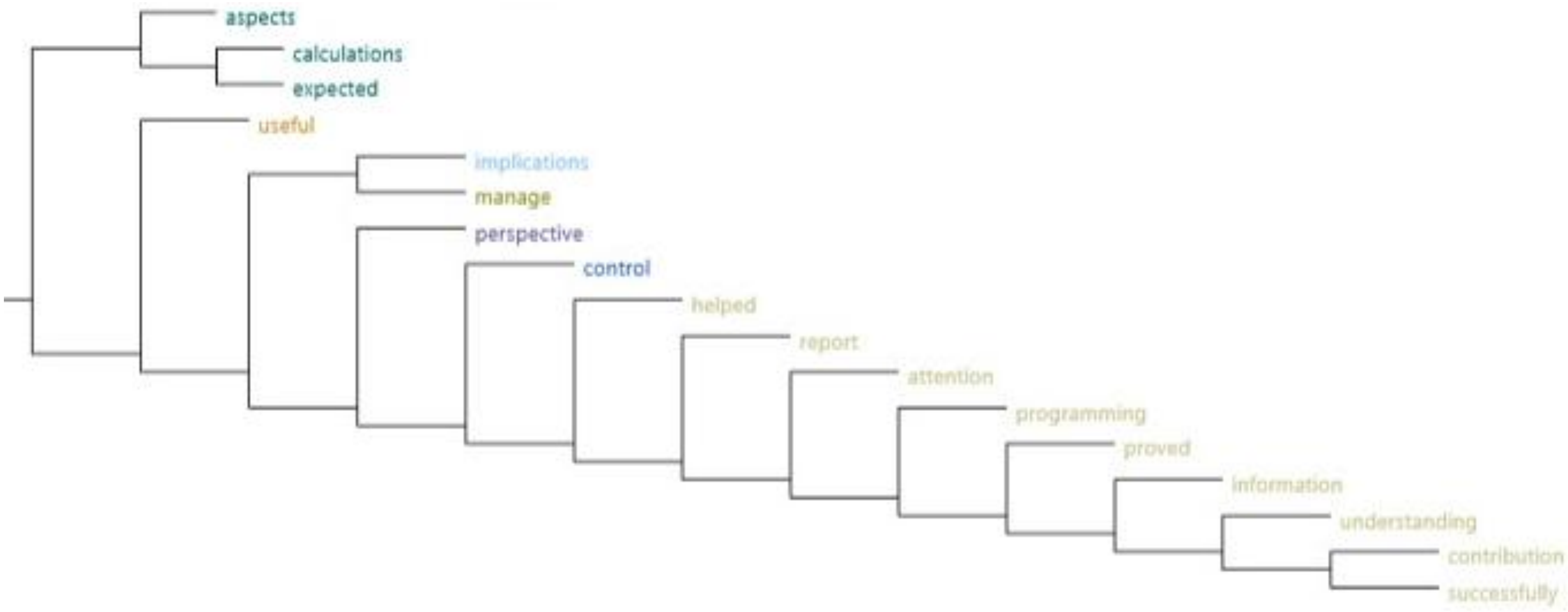


Figure 4-15: Core Competency of Electrical Engineering Cluster 2

INDUSTRIAL ENGINEERING

A word cluster was created for the core competencies of the Industrial Engineer and returned several clusters:

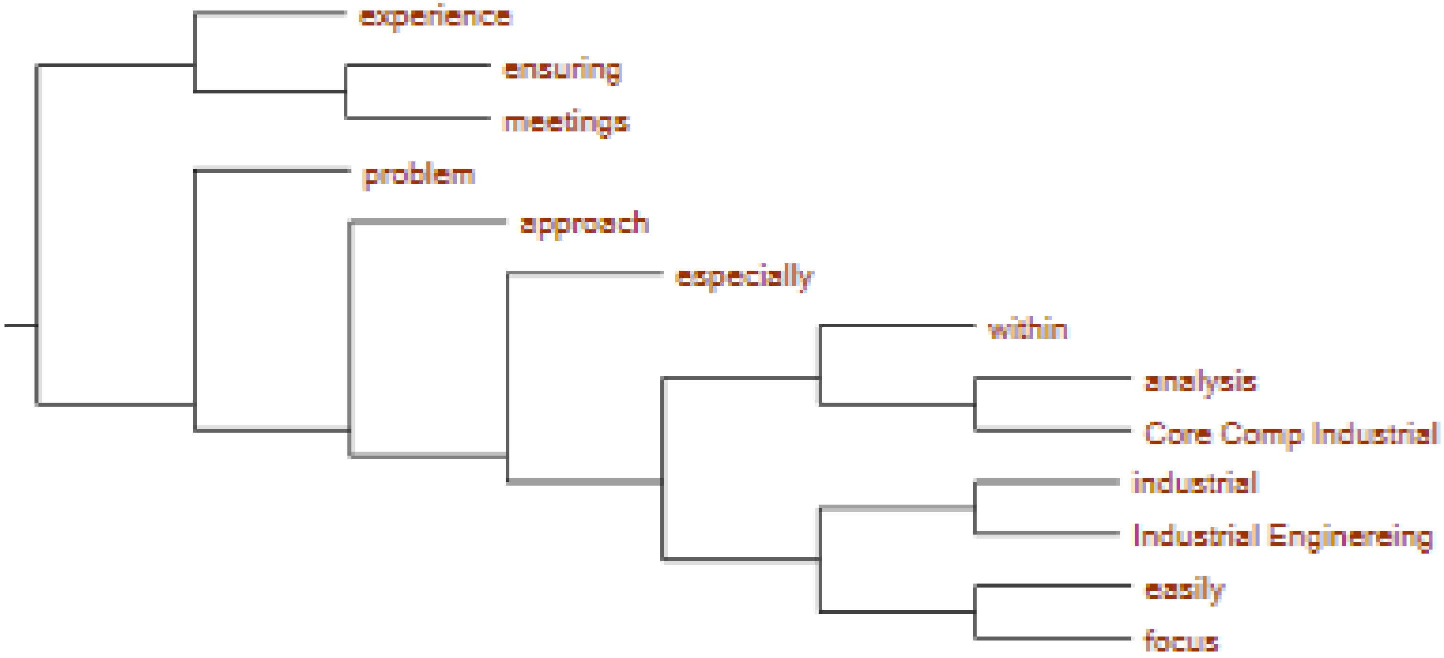


Figure 4-16: Core Competency of Industrial Engineering Cluster 1

The first cluster identifies the approach taken by the student, indicating that they seem to be experienced in organisation, and ensure that meetings occur, identifying them as astute project managers. Secondly, it is seen that the Industrial Engineer seems to approach problems with focus, and easily.

Figure 4-17: Core Competency of Industrial Engineer Cluster 2

The second cluster (Figure 4-17) is vast in scope, and bolsters the first cluster. It identifies that Industrial Engineering students are heavily involved in the coordination of systems and administration. The blue cluster shows the level of involvement, with Industrial Engineers playing active roles in the report and studies. It is also interesting to note that students assumed that the Industrial Engineer would take ownership of both leadership and decision making. The skills of the Industrial Engineer are described in terms of operations and processes and the application and execution thereof. It is also shown that the Industrial Engineers are expected to view identify and decide on issues, and that they are effective in this regard.

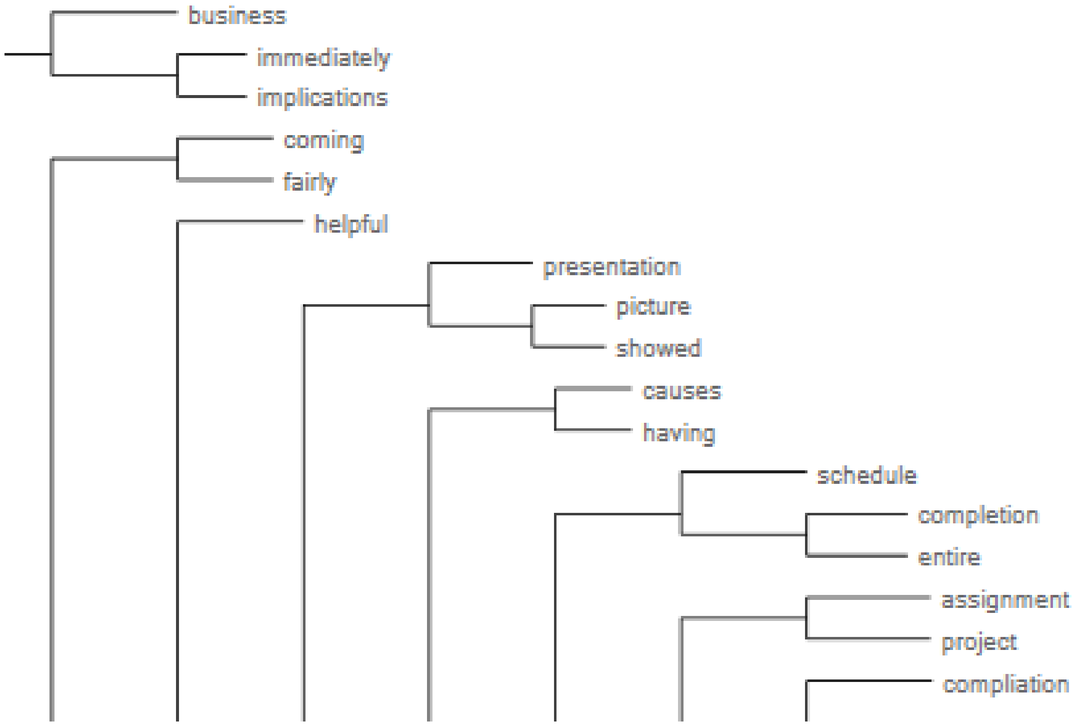


Figure 4-18: Core Competency of Industrial Engineering Cluster 3

The third cluster identifies the Industrial Engineers approach to “business” aspects, immediately identifying the implications. It explores assistance provided by Industrial Engineers regarding presentation – the actual presentation as well as presentation of ideas visually – and identifies that they assist with root cause identification. There is mention of scheduling, which, based on the structure of the cluster, indicates that the industrial engineers assisted greatly with the compilation and completion of the project.

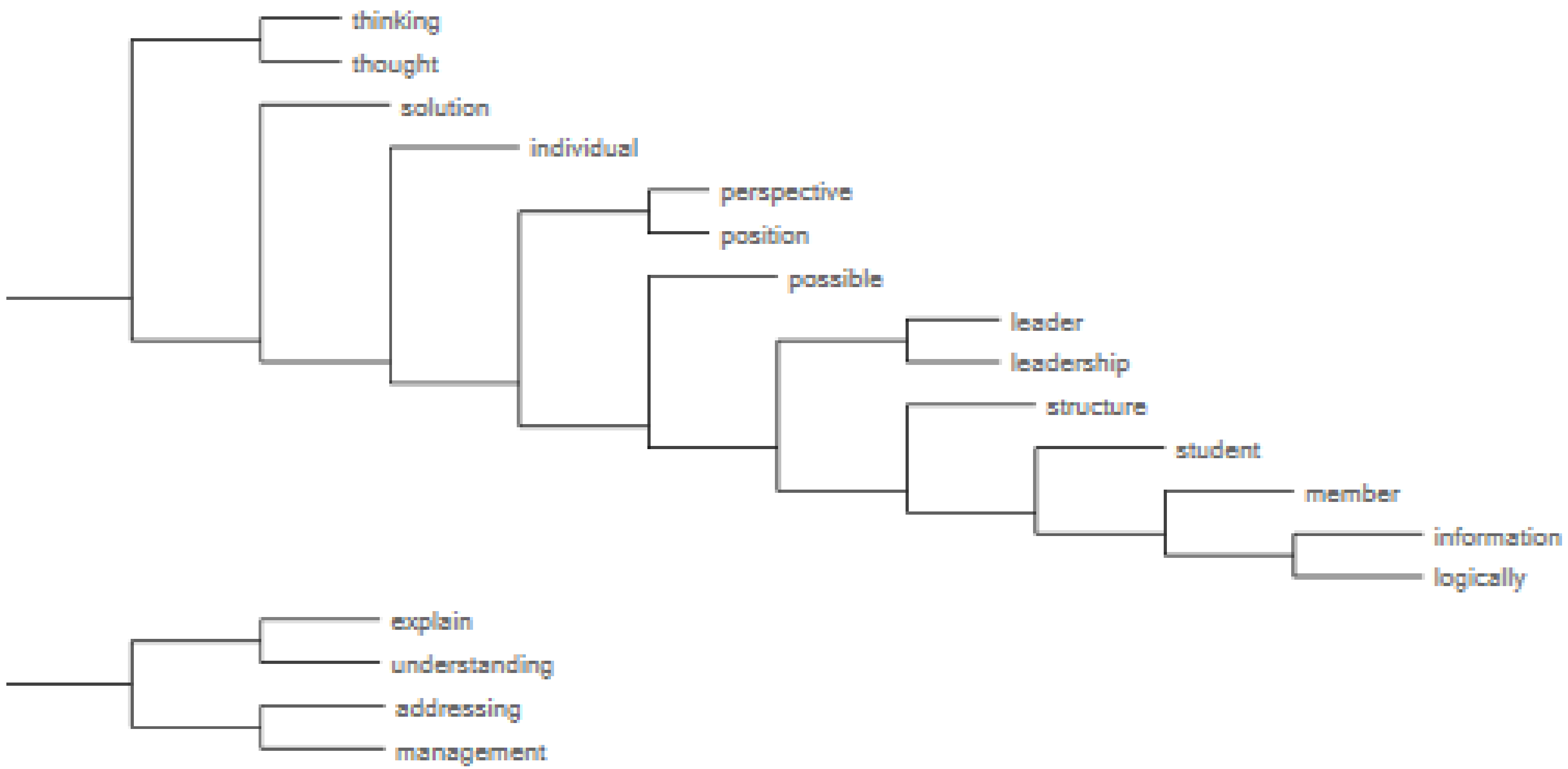


Figure 4-19: Core Competency of Industrial Engineering Cluster 4

The Industrial Engineer's thought process (Figure 4-19) is considered as solution oriented, and provides different perspectives, and communicates these perspectives by using their leadership skills. There is a small cluster that indicates that the Industrial Engineer and the Information Engineer share the same "logical" approach. The final cluster indicates that Industrial Engineers are proficient at both understanding and explaining to other students, and are succinct at addressing other students and perform a managerial role.

The emergent themes for the core competencies of Industrial Engineers are identified as:

- Project Managers
- Assumed Leader and Decision Maker
- Operations and Process Driven
- Business Driven
- Leadership

Information Engineering

A word cluster is created for the core competencies of the Information Engineer and returned several clusters:

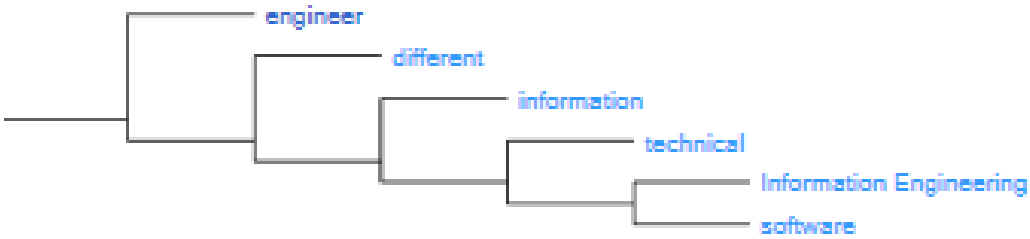


Figure 4-20: Core Competency of Information Engineering Cluster 1

The most prominent cluster identifies that the Information Engineers are seen as specialized, in that they are "different" and mostly dealt with software (Figure 4-20)

.

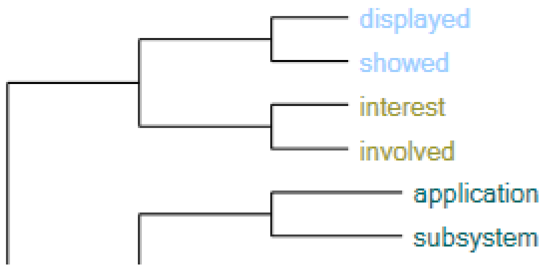


Figure 4-21: Core Competency of Information Student Cluster 2

This cluster confirmed that Information Engineers displayed interest and stayed involved, but only on an application and, therefore, subsystem level. The following sub-clusters elaborate on the above emergent theme:

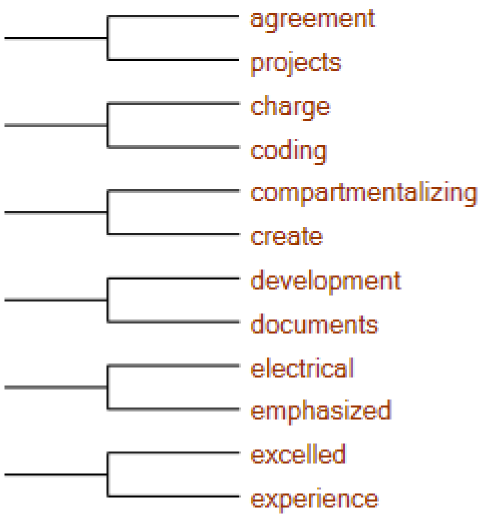


Figure 4-22: Core Competency of Information Engineering Cluster 3

The above sub-cluster (Figure 4-22) highlights the ‘compartmentalizing” that is experienced with Information Engineering, indicating that their core competencies resided in development and creation of documentation, and taking charge for any coding required. It is noted that the Information Engineers’ emphasized electrical aspects

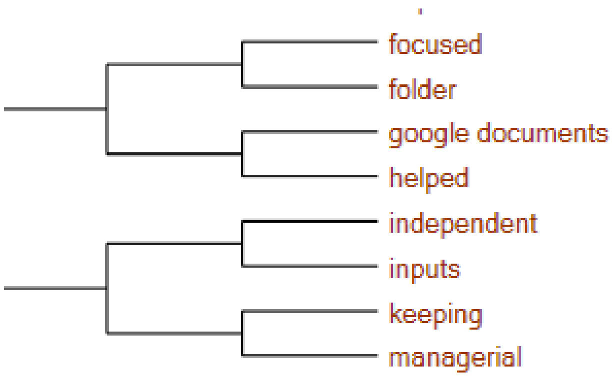


Figure 4-23: Core Competency of Information Engineering Cluster 4

Finally, it is shown that the main contribution of the Information Engineers is the management of inputs by the use of shared folders and Google documents, allowing independent inputs from other disciplines.

The emergent themes for the core competencies of Information Engineers are identified as:

- Software-oriented
- Documentation Formatting
- Electrical Aspect
- Collaboration of Inputs

Mechanical Engineering

A word cluster was created for the core competencies of the Mechanical Engineer and returned several clusters:

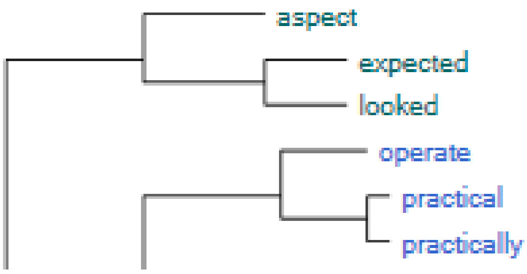


Figure 4-24: Core Competency of Mechanical Engineering Cluster 1A

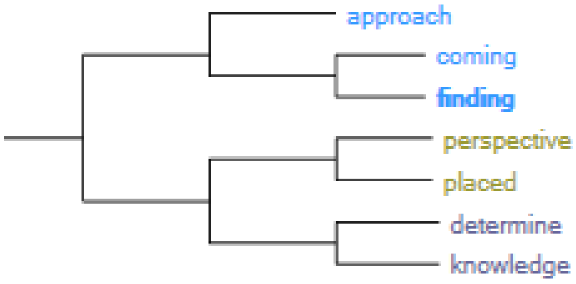


Figure 4-25: Core Competency of Mechanical Engineering Cluster 1B

The initial cluster identified the practical approach that the Mechanical Engineers take, as opposed to the reflected "abstract" approach to the Electrical and Information Engineers.

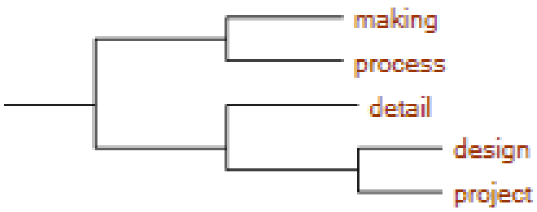


Figure 4-26: Core Competency of Mechanical Engineering Cluster 2

It is shown that the Mechanical Engineers then process each detail from a design perspective.

What is unique to the Mechanical Engineers is their entire approach to the project and the interplay between the disciplines, in that they worked with specific engineers for parts of the project (Figure 4-27).

Their initial understanding and thinking was strongly correlated with the Industrial Engineer, thereafter analysing the project, with the term "better" shown. It is interesting to note that the Industrial Engineer was strongly correlated with "responsible", and is identified with their emergent theme of leadership.

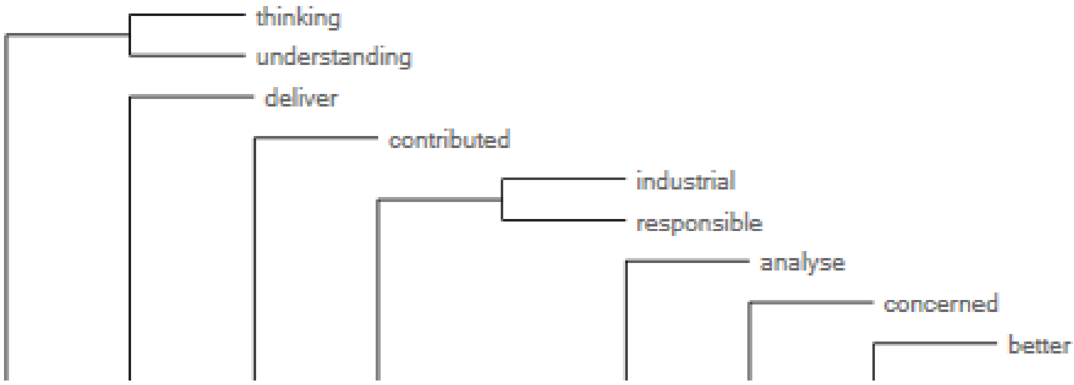


Figure 4-27: Core Competency of Mechanical Engineering Cluster 4

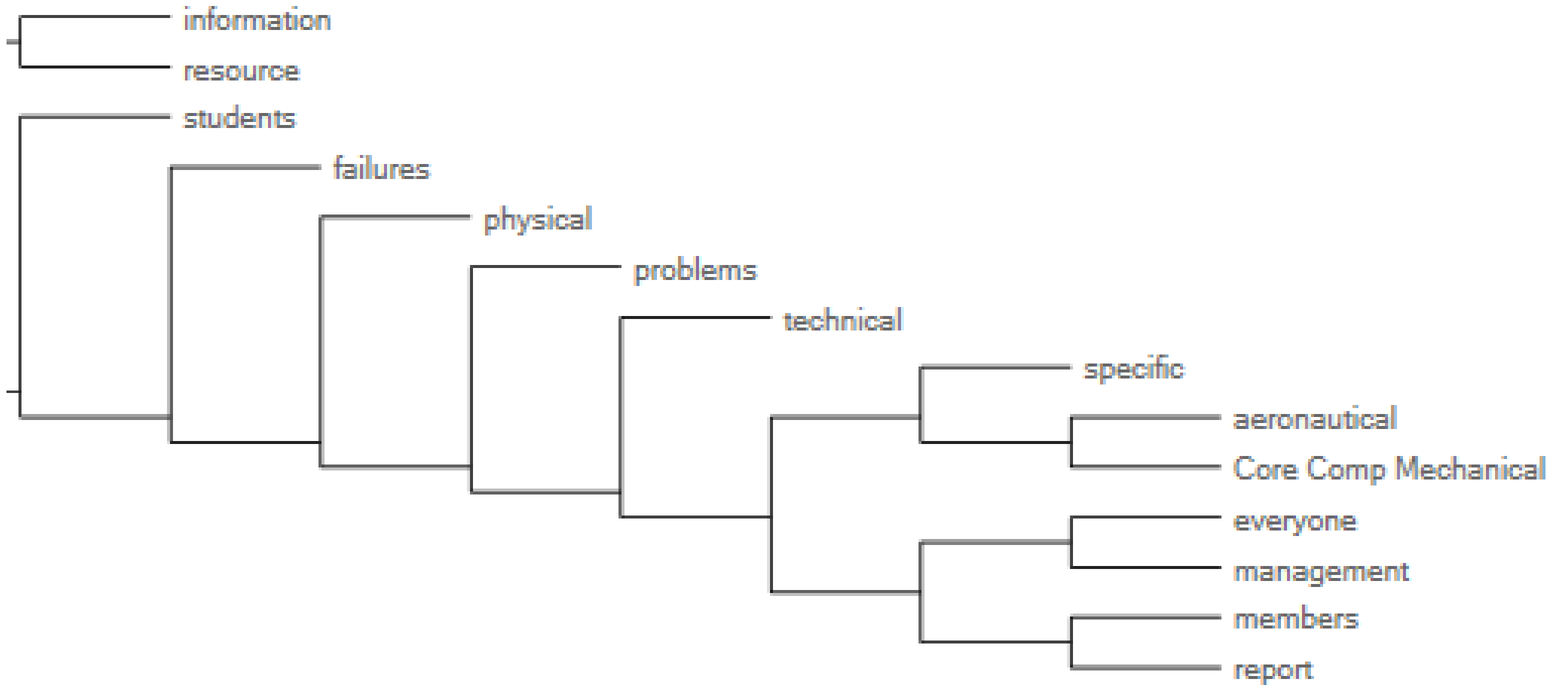


Figure 4-28: Core Competency of Mechanical Engineering Cluster

The Mechanical students' thereafter combine resources and information, and then move into their area of specialisation, considering failures, and technical and physical problems. It is evident that the Mechanical Engineers rely on other students for specific details or functions i.e. they separate their core competency from those described as "aeronautical", "management" and "report". It is noted that the Mechanical Engineers core competency is well aligned to that of the aeronautical engineer in terms of detail – "specific".

The emergent themes of the core competencies of the Mechanical Engineers are identified as:

- Practical Approach
- Analysis of Each Requirement
- Mechanical Aspect

4.4.2 Student Opinions on Different Disciplines

Any opinions given by students – that is, any reflection of a discipline that is not substantiated by the student with a particular task or core competency completed – will be coded as the opinion given rather than a core competency. As suggested, the "flip-flop" technique is then used for the dimensioning of discipline differences, and coding shall consider both positive and negative aspects.

Coding will include:

- Positive/neutral commentary -any positive or neutral comments made by a student on another discipline or individual from a particular discipline, including concepts that were found to be interesting.
- Negative commentary - any criticism that is made by a student on another discipline or individual from a particular discipline

It is noted that the core competency and positive reflections of students for each discipline will be compared, using Pearson's correlation. If they are found to be similar, no further exploration of the positive commentary regarding that discipline will be done. If the Pearson's correlation is low (less than 0.70) (BMGI, 2013), all coding will be analysed further to identify specific causal and central phenomenon that would indicate the correlation between different disciplines, their core competencies and their opinions of other disciplines

AERONAUTICAL ENGINEERING

A comparison of positive and negative in regard to the students' opinions for Aeronautical Engineers was completed, whereby each student that gave an opinion was compared to the total amount of students per discipline.

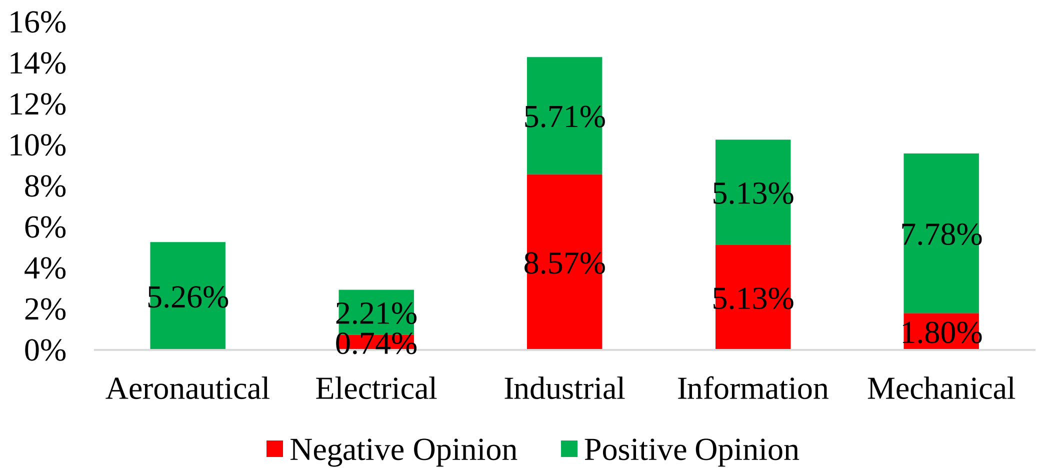


Figure 4-29: Comparison of Positive vs Negative Feedback of Aeronautical Engineers

Aeronautical Engineers did not reflect any negative opinions of their own discipline (Figure 4.29). The Industrial Engineers were the only discipline to have a higher percentage of negative opinions when compared to positive, regarding the aeronautical students.

A Pearson's correlation was used to compare core competencies to positive opinions (n=25) of Aeronautical Engineers, and yielded the following:

Figure 4-30: Aeronautical Engineering Positive Correlation

Emergent themes for positive opinions of aeronautical engineers will, therefore, be considered similar to core competencies and will not be explored further.

To identify whether there were distinct differences between the positive/neutral opinions of Aeronautical students versus the negative opinions given (n=12), a correlation test was used and yielded a Pearson's correlation of 0.782, indicating that several students identified that the same attributes were either negative or positive.

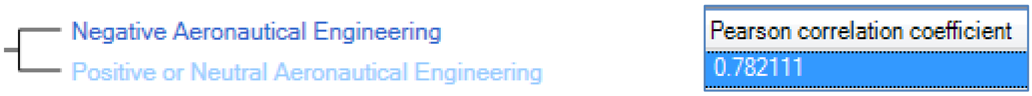


Figure 4-31: Aeronautical Engineering Negative Correlation

Cluster analysis on negative coding identified the following themes:

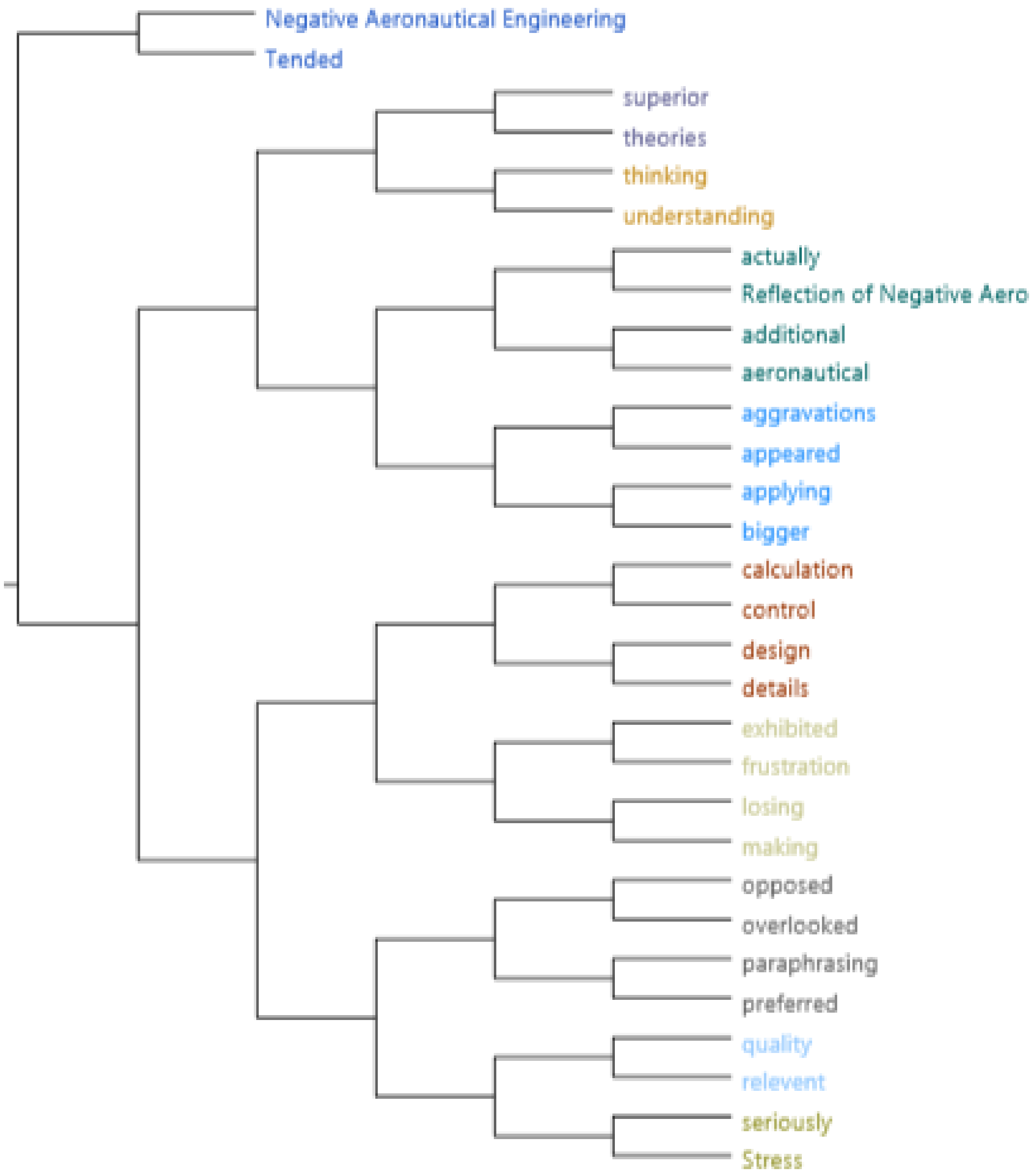


Figure 4-32: Negative Opinion of Aeronautical Engineer Cluster 1

It is shown that the negative opinions of students centred on the fact that aeronautical students tended to act in a "superior fashion" regarding certain theories and understanding. This may be bolstered by the fact that not a single aeronautical engineer gave negative feedback in regard to their discipline. It also seems that fellow team members were frustrated at the aeronautical engineers' tendency to paraphrase and place a large focus on details, calculations and design, with some students identifying the "aggravations" associated with the aeronautical engineers not seeing the bigger picture. The small sample size suggests that this should not be considered as a general emergent theme, but should be considered for further research in the future.

ELECTRICAL ENGINEERING

A comparison of positive and negative in regard to the students' opinions for electrical engineers was completed, whereby each student that gave an opinion was compared to the total amount of students per discipline.

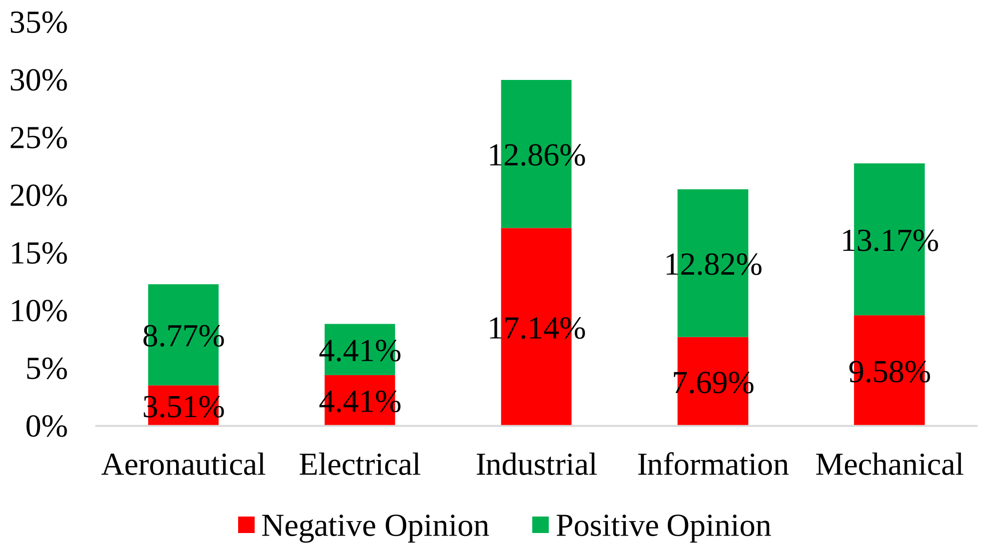


Figure 4-33: Comparison of Positive vs Negative Feedback of Electrical Engineers

The biggest critique of electrical engineers by percentage was from industrial students, who were also the only group to express a more negative opinion than a positive one. It is interesting to note that the electrical engineers had a 50% split opinion of their own discipline, and that the mechanical and aeronautical engineers were slightly more positive about the electrical engineers. Strangely, the information students, though from the same school, reflected a similar split of opinion when compared to the mechanicals.

A Pearson’s correlation was used to compare core competencies to positive opinions (n=47) of electrical engineers, and yielded the following:

Figure 4-34: Electrical Engineering Positive Correlation

Emergent themes for positive opinions of electrical engineers will, therefore, be considered similar to core competencies and will not be explored further.

To identify whether there were distinct differences between the positive/neutral opinions of electrical students versus the negative opinions given (n=39), a correlation test was used and yielded a Pearson’s correlation of 0.912, indicating that several students identified that the same attributes were either negative or positive.

Figure 4-35: Electrical Engineering Negative Correlation

Cluster analysis on negative coding will be split due to the spread of the following identified themes:

In Figure 3-36, the first cluster identifies the unsatisfactory management style of the electrical engineer, and shows that the electrical engineer’s approach to the project was technically orientated, and thus inclined to their discipline, which would create tension once the group members tried to combine their individual contributions. It also shows that the clashes occurred predominantly with mechanical engineers.

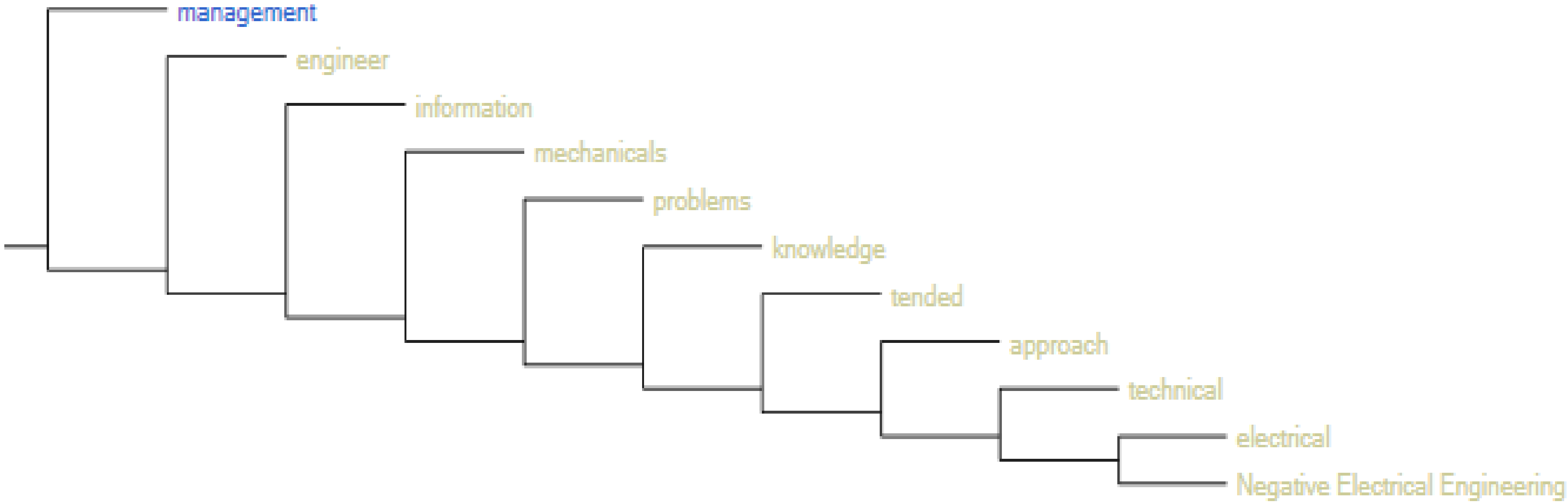


Figure 4-36: Negative Opinion of Electrical Student Cluster 1

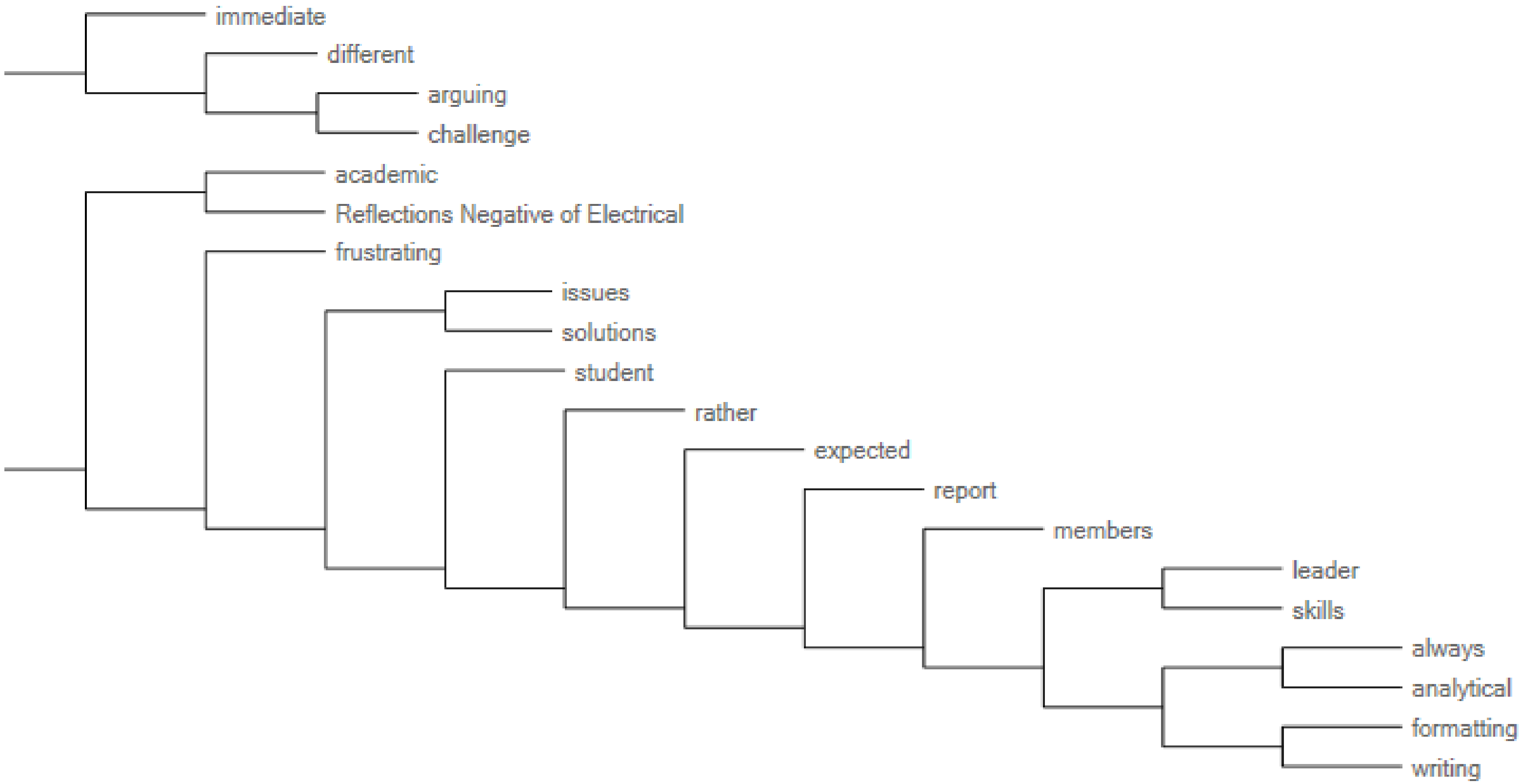


Figure 4-37: Negative Opinion of Electrical Student Cluster 2

The second cluster indicates an almost immediate clash of opinions, as indicated by the words “arguing” and “challenge”. It is shown that the approach of the electrical engineer is “academic” and “frustrating” and further exploration substantiates the previous cluster by identifying that the electrical engineers delve into analytical details. It also identifies with an emergent theme from the comparison of schools, indicating that report formatting was a complication with this particular discipline when compared with the others.

Industrial Engineering

A comparison of positive and negative in regard to the students’ opinions for Industrial Engineers was completed, whereby each student that gave an opinion was compared to the total amount of students per discipline.

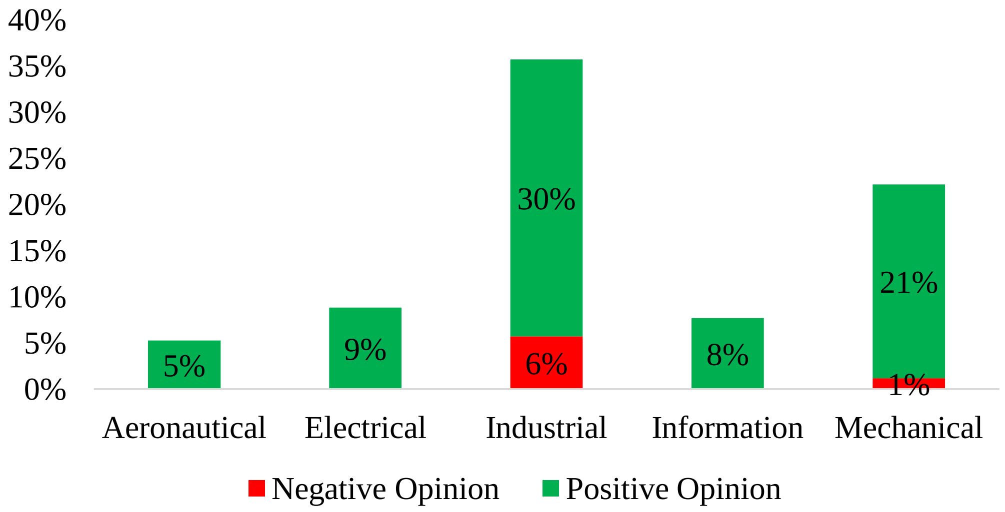


Figure 4-38: Comparison of Positive vs Negative Feedback of Industrial Engineers

The opinions of other disciplines on the Industrial Engineer is unique in that all disciplines had an overall positive opinion. The Industrial Engineers had a very positive opinion of their own discipline, but were also their own biggest critics. The only other discipline to have a negative opinion on the Industrial Engineer was the Mechanical Engineer, with a very small percentage (1%).

A Pearson’s correlation was used to compare core competencies to positive opinions (n=74) of industrial engineers, and yielded the following:

Figure 4-39: Industrial Engineering Positive Correlation

Emergent themes for positive opinions of Industrial Engineers will, therefore, be considered similar to core competencies and will not be explored further.

To identify whether there were distinct differences between the positive/neutral opinions of Industrial students versus the negative opinions given (n=5), a correlation test was used and yielded a Pearson’s correlation of 0.659, indicating that several students identified that there were unique or different reasons for their negative opinion of Industrial Engineers.

Figure 4-40: Industrial Engineering Negative Correlation

Cluster analysis on negative coding identified the following themes:

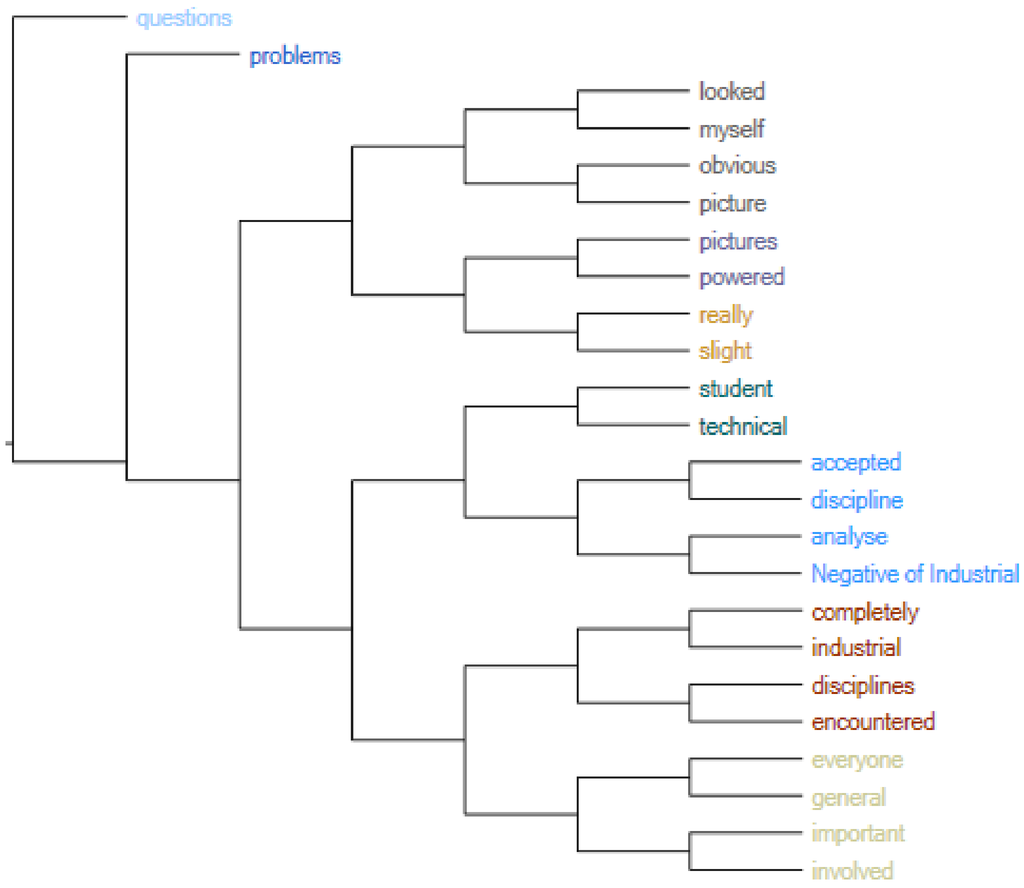


Figure 4-41: Negative Opinion of Industrial Engineer Cluster 1

As the above cluster is to be read in a negative context, it is understood that other disciplines felt that the Industrial Engineer asked too many questions, which created problems. It further expands into two separate sub-clusters. The first sub-cluster indicates that the Industrial Engineer was considered less technically inclined. It further alludes to Industrial Engineers constantly looking for the "bigger picture", which may be frustrated to more specialised disciplines.

The second sub-cluster identifies the Industrial Engineering as too general and too involved, which is similar to the first subcluster. The negative opinions of Industrial Engineers, therefore, centre on "Less Technically Inclined", "Inquisitive" and "Generalised".

INFORMATION ENGINEERING

A comparison of positive and negative in regard to the students' opinions for Information Engineers was completed, whereby each student that gave an opinion was compared to the total amount of students per discipline.

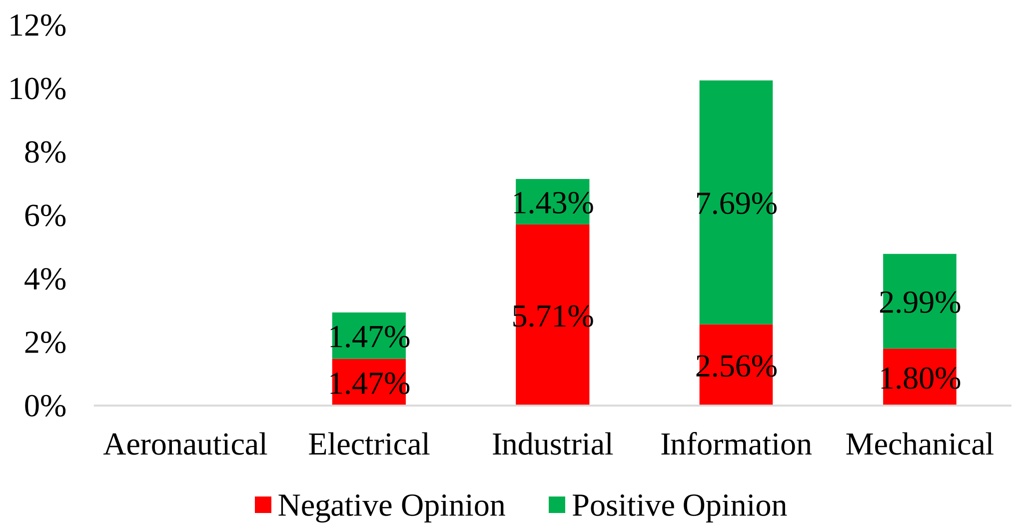


Figure 4-42: Comparison of Positive vs Negative Feedback of Information Engineers

An anomaly is seen here, as it is the only time one branch has not given an opinion on another (Aeronautical Engineering). It is also noted that it is the second time that the Electricals have had a 50% split decision on a discipline, with the first instance that of their own opinion on their own branch. This is interesting, as the Information Engineers and Electrical Engineers are from the same school. The Industrial Engineers have are the only discipline to have a mostly negative opinion.

A Pearson's correlation was used to compare core competencies to positive opinions (n=11) of Information Engineers, and yielded the following:

Figure 4-43: Information Engineering Positive Correlation

Emergent themes for positive opinions of information engineers will, therefore, be considered similar to core competencies and will not be explored further.

To identify whether there were distinct differences between the positive/neutral opinions of Information students versus the negative opinions given (n=10), a correlation test was used and yielded a Pearson's correlation of 0.722, indicating that several students identified that a majority of the same attributes were either negative or positive.

Figure 4-44: Information Engineering Negative Correlation

Cluster analysis on negative coding will be split due to the spread of the following identified themes:

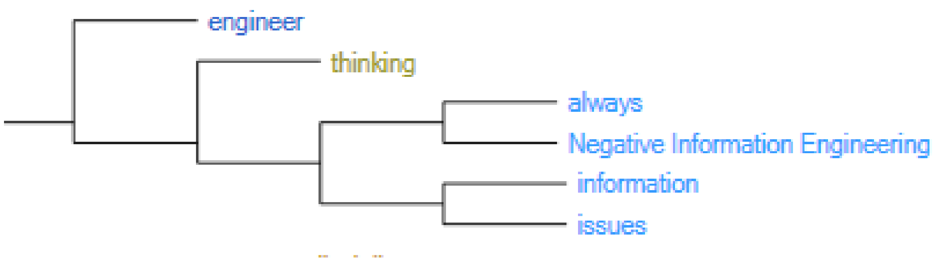


Figure 4-45: Negative Opinions of Information Engineers Cluster 1

As the above is coded negatively, it alludes to the fact that Information students have a very specific way of identifying issues. The word 'always' advocates that Information students are very specialized.

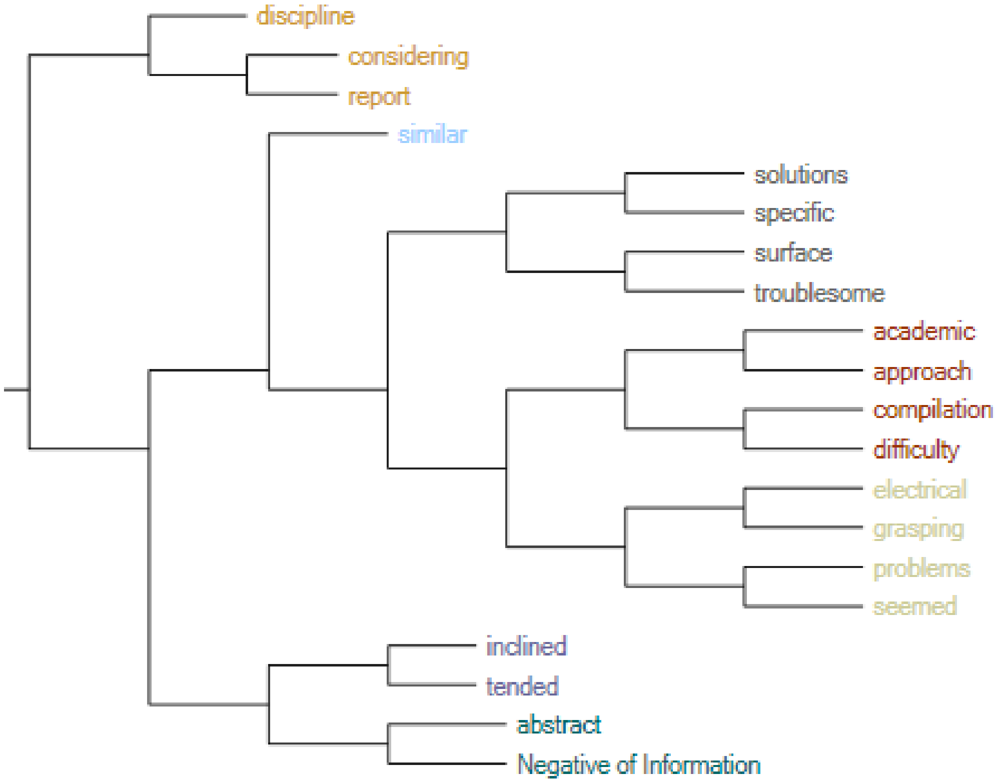


Figure 4-46: Negative Opinions of Information Engineers Cluster 2

It is evident that the report was problematic for the Information student, which coincides with what was discovered by the Electric Engineering discipline, and the School of EI as well. The cluster alludes to the approach of Information Engineers as ‘surface’ and ‘troublesome’, and identifies that the solutions provided by them were very specific. The cluster further identifies that the approach of the Information Engineer was similar to that of the Electrical Engineer in that it was very academic, and in context of the report writing, would allude to the use of paraphrasing and jargon. This idea is bolstered by the last sub-cluster, identifying the abstract approach of Electrical Engineers.

Mechanical Engineering

A comparison of positive and negative in regard to the students’ opinions for Mechanical Engineers was completed, whereby each student that gave an opinion was compared to the total amount of students per discipline.

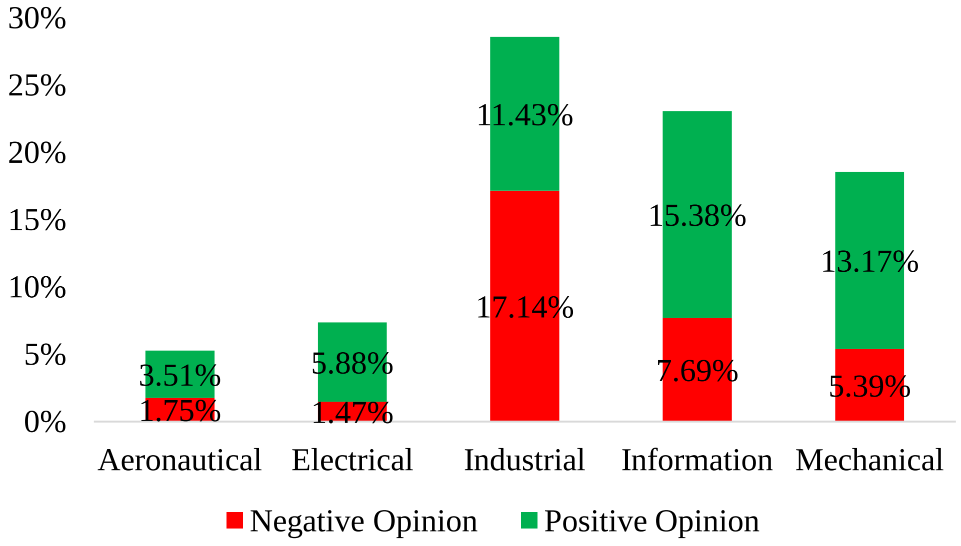


Figure 4-47: Comparison of Positive vs Negative Feedback of Mechanical Engineers

Industrial Engineers have the most negative opinion of the Mechanical Engineering students, as well as the only discipline that has a more negative than positive opinion of Mechanical Engineering students. The Mechanical Engineering students have quite a large negative opinion of their own discipline (5.39%)

A Pearson's correlation was used to compare core competencies to positive opinions (n=46) of Mechanical Engineers, and yielded the following:

Figure 4-48: Mechanical Engineering Positive Correlation

Emergent themes for positive opinions of Mechanical Engineers will, therefore, be considered similar to core competencies and will not be explored further.

To identify whether there were distinct differences between the positive/neutral opinions of mechanical students versus the negative opinions given (n=27), a correlation test was used and yielded a Pearson's correlation of 0.889, indicating that several students identified that the same attributes were either negative or positive.

Figure 4-49: Mechanical Engineering Negative Correlation

Cluster analysis on negative coding will be split due to the spread of the following identified themes:

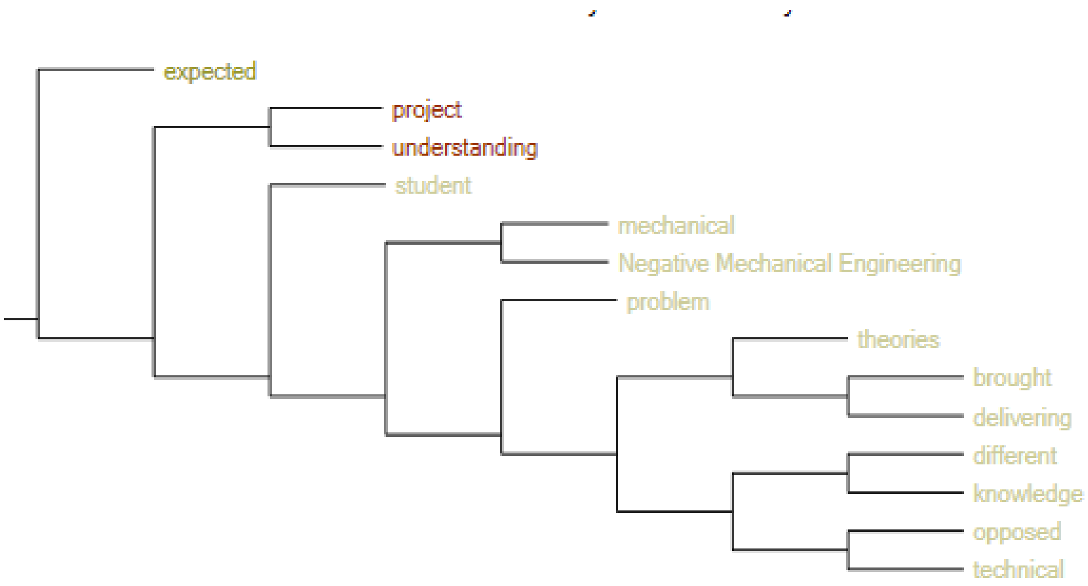


Figure 4-50: Negative Opinions of Mechanical Engineers Cluster 1

As the above cluster is coded for negative context, it is assumed that most students expected the Mechanical Engineers to have a sound understanding of the project, which was not experienced. The cluster further identifies that students had issues with the Mechanical Engineers and the theories they brought to the project, citing them as technical and opposed.

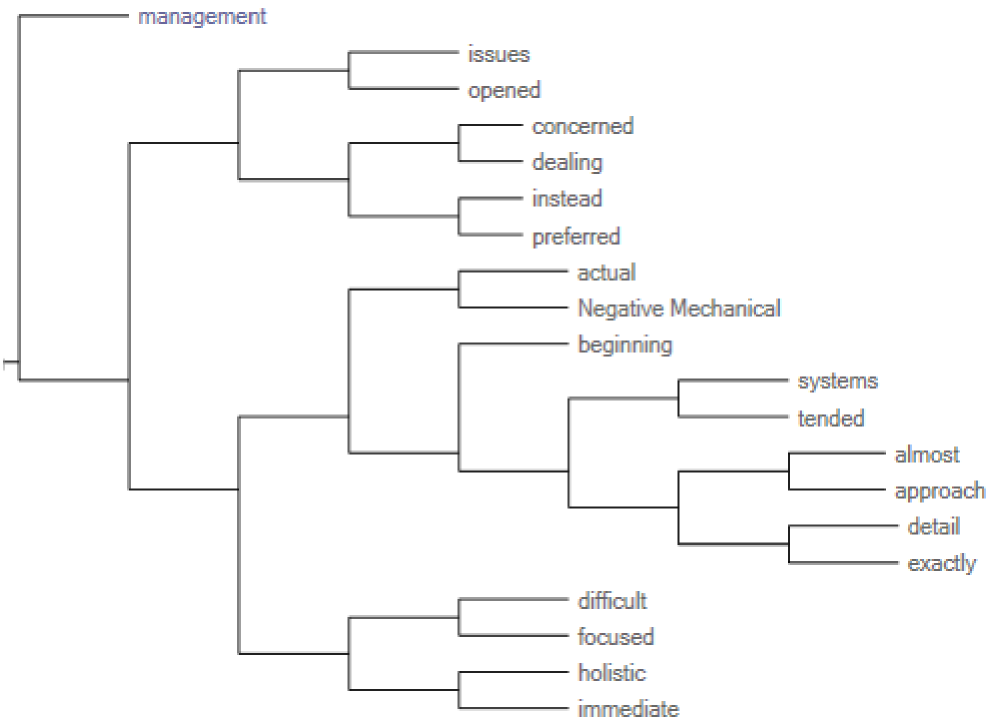


Figure 4-51: Negative Opinions of Mechanical Engineers Cluster 2

Management by the Mechanical Engineers was identified as problematic for two reasons. The first sub-cluster identifies that the Mechanical Engineers may have approached the project with from their discipline only, in that they preferred to deal with issues pertaining specifically to Mechanical Engineering, thus having pre-conceived solutions without considering the entire project. The small sub-cluster identifies the difficulty that the Mechanical Engineers have with holistic approaches, as they preferred to focus on issues that could immediately be solved. It must be noted that the term “beginning” may allude to the fact that this issue was resolved by the end of the project, and that Mechanical Engineers may well have learned to adopt a holistic, or systems, approach.

4.5 Other Emergent Themes

Several themes have emerged that may be explored in future research. The themes identified as discourse are as follows:

Personality Clashes

In certain instances, individuals expressed clashes between students as being personal in nature, and having very little to do with disciplinary differences. It may be that group dynamics may play a larger part of conflict than the disciplines themselves. The percentage of students' coded for the above reason are compared in a graph below, relative to their discipline sample group:

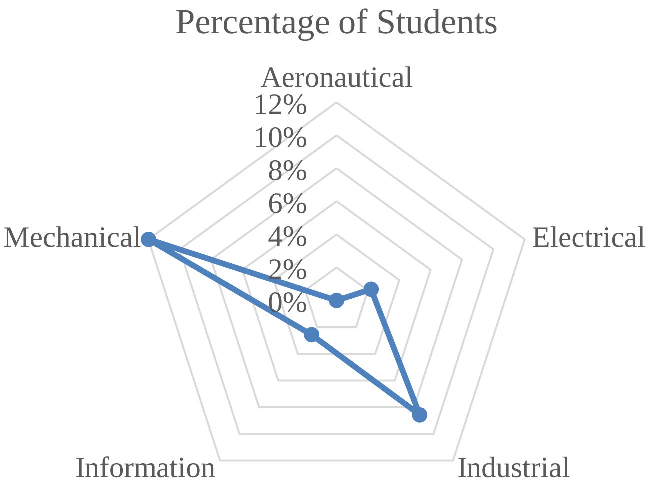


Figure 4-52: Radar Graph of Disciplines that Identify Personality Clashes

Examples of coded "Personality Clashes" have been provided below:

> *"It must be noted that these challenges may not have been due to the disciplines but rather due to personality differences"* – Industrial Engineer

> *"I think that the group dynamic was affected to a greater extent by the individual personalities of the group rather than by the multidisciplinary context of the group dynamics."* – Information Engineer

> *It is more a function of individuality, rather than separate schools imposing a particular style of working. The author*

believes that there has been no effort in imparting working skills on students by the school, and such difference of school cannot be a factor. – Mechanical Engineer

Particular mention should be made of the incidence of egotism and bigotry mentioned, and some coded reflections of these instances are given below:

"I occasionally sensed a slight arrogance in some group members in that they felt engineering was more prestigious and that their projects were more important than other engineers." – Electrical Engineer

"The most significant of these … was that other schools are also of the opinion that they are the superior branch of engineering, most notably the Aeronautical Engineering Students." – Electrical Engineer

"The reality of the situation lead to frustration and the need for the control of egos when came to decision making - the Aeronautical and Electrical students were particularly tested in this regard." – Mechanical Engineer

"Also the extreme degree of their awesomeness should be noted."
– Electrical Engineer

There were instances were a combination of discipline and the ego of the student combined:

Interestingly enough, one evening when the meeting session was over, someone the Electrical asked the question: What is the job of a Mechanical engineer in the real world? This opened a new can of worms resulting in an in-depth .discussion (which took about half an hour) concerning the two disciplines: Mechanical and Electrical engineering – Electrical Engineer

Gender Division

Largely discordant within the research, gender division was mentioned a few times. The researcher feels that this particular topic is largely under-represented in the reflections of students, and concedes that admissions of this nature may be frowned upon by most team members.

Some reflections coded for gender division are given below:

> *"However, on numerous occasions there was a clear divide along gender lines: the men had one opinion and the women another"* – Electrical Engineer

> *"Being the only female in the group was an advantage. The males showed respect and listened to my opinion on most things though not always listening to their male counterparts. However, I feel that it is actually a form of sexism. In the workplace, sexism can lead to biases when it comes to the division of work, evaluations and promotions. Everyone should be able to pull their own weight."* – Electrical Engineer

> *"I did notice that the men in the group seemed to take much more time fiddling with inconsequential details. This did not affect the work they did at all as we all ensured we have an equal work load, but it sometimes appeared that they would spend 45 minutes fiddling with a detail as the page margin to get it just right. Although this attention to detail can be good sometimes, it did tend to get a little frustrating to watch it happen while we were waiting to move onto the next section of work"* – Mechanical Engineer

> *"Although I did not see a difference between the different groups, I saw a difference between male and female students. Female students were faster in putting the work together and*

seemed not to over complicating the problem" – Mechanical Engineer

"It is also very interesting to work with a girl (since there are so few in engineering)." – Information Engineer

The following was isolated may not be deemed significant, but are worth mentioning:

Language Barriers – "*The language barrier was a problem during communication. For English as a second language, it was difficult to understand and analyse the project."*

Disciplinary Bias - "*Due to the number of mechanicals in the group we had a bias towards a mechanical conclusion"*

Ageism – *"Age disparities lead to the difficulties on how address certain individuals e.g. jokes and diction"*

4.6 Summary of Emergent Themes

A summary of emergent themes is provided, so that the deductive analysis that follows may be explained by certain phenomena uncovered by inductive analysis.

4.6.1 CODING: CONFLICT

A summary of the emergent themes around conflict are given below:

Table 4-2: Summary of Emergent Themes for "Conflict"

Coding	Primary Themes	Emergent Themes
Conflict	General Conflict	Schedule, Management, Resolution, Approach, Group Formation, Effective Communication
	Conflict Mentioning MIA	Difference Between Schools In Format and Compilation of Documents, Separation of Electrical Engineers
	Conflict Mentioning EI	Separation of Electrical Engineers, Difference in Presentation between the School of MIA and the School of EI and The Abstract Approach of the School of EI

The conflicts between schools are similar, and are mostly based upon the differences in presentation, documentation and compilation. In-vivo, a majority of the students overcame this obstacle by using effective communication. In line with the lecturers' open-ended questions, it is seen that the students reflected on the questions well, identifying schedule, management, resolution, approach, group formation and effective communication, which used the coding of "Project Management".

4.6.2 Coding: Differences in Disciplines

Table 4-3 : Summary of Positive vs. Negative Opinions using Pearson's Correlation

Coding	Discipline	Pearson's Correlation to Core Competency	
		Positive Opinion	Negative Opinion
Difference in Disciplines	Aeronautical	0.8056	0.7821
	Electrical	0.913	0.9124
	Industrial	0.9563	0.6587
	Information	0.7486	0.722
	Mechanical	0.8684	0.8888

It is noted that the negative opinions concerning Industrial Engineers were the only Pearson's correlation that did not correlate above 70%, indicating that the negative opinions around Industrial Engineers were considered separate from their core competencies.

Table 4-4: Summary of Emergent Themes for "Disciplines" - "Core Competencies"

Coding	Discipline	Core Competency
Difference in Disciplines	Aeronautical	Explaining Technical Aspects, Design Driven, Leadership in Technical Aspects
	Electrical	Detailed Assistance in Software Leadership in Calculation and Programming
	Industrial	Project Managers Assumed Leader and Decision Maker Operations and Process Driven Business Driven Leadership
	Information	Software-oriented, Documentation Formatting Electrical Aspect, Collaboration of Inputs
	Mechanical	Practical Approach Analysis of Each Requirement Mechanical Aspect

Reflecting on the above table, it is seen that all disciplines are quite aspect driven, with the Industrial Engineers more systems-driven. All negative opinions were explored, yet the Industrial Engineer was the only discipline where the core competencies did not correlate strongly with the negative opinions, and thus differed to the core competencies. The negative opinions of Industrial Engineers centred on "Less Technically Inclined", "Inquisitive" and "Generalised".

4.6.3 CODING: ADDITIONAL THEMES

There are other themes that are mentioned in a few instances, but should be identified for future research.

Table 4-5: Summary of Emergent Themes for Coding Additional Themes

Coding	Emergent Theme
Discourse	Personality Clashes
	Gender Division
	Language Barriers
	Disciplinary Bias
	Ageism

4.7 ECSA Outcomes Exit Level 8

4.7.1 FRAMEWORK OF REQUIREMENTS

Questions pertaining to whether the subject meets the ECSA outcome level requirements may be categorized underneath each hypothesis, as outlined by ECSA (Engineering Council of South Africa, 2003c)

H_1: THE CANDIDATE DEMONSTRATES EFFECTIVE TEAM WORK

Does the student:

- Make individual contributions to the team activity?
- Perform critical functions?
- Benefit from team members?

- Enhance the work of fellow team members?
- Communicate effectively with team members?
- Deliver completed work on time?

H_2: THE CANDIDATE DEMONSTRATES MULTIDISCIPLINARY WORK

Does the student:

- Communicate across disciplinary boundaries?
- Use a systems approach?
- Acquire a working knowledge of co-workers' discipline?

It is to be noted that the requirement that the candidate demonstrates effective individual work be excluded from hypothesis testing. It is outside the scope of student reflections and questions such as focus on objectives, strategic working, effective task execution and delivery of completed work on time would not be determinable by the reflections of the students (Engineering Council of South Africa, 2003c).

4.7.2 ANALYSIS PERFORMED USING NVIVO

It must be noted that NVivo does not code the raw data at all. All coding is completed by the researcher. NVivo only assists with word queries and provides correlation values between topics coded by the researcher.

Each requirement outlined by ECSA was used to create a node, whereby in-vivo analysis of the students' reflections was used to ascertain whether they were met. Hierarchical node creation was used, so that the ECSA Exit Levels Outcome was considered the primary node, with two child nodes for each suggested hypothesis:

- Does the candidate demonstrate effective team work?
- Does the candidate demonstrate multidisciplinary work?

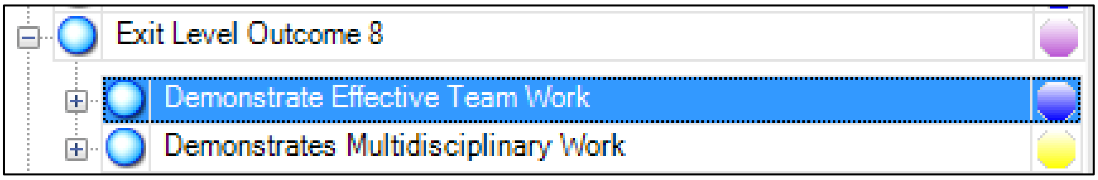


Figure 4-53: Hypothesis Coding in NVivo

Each child node developed for the hypotheses in turn had their own children nodes, so that each sub-requirement could be coded for. An example is shown below, whereby each child node had a dichotomous scale included for coding, but also allowed for the coding of reflections in instances where it was not clear whether the requirement had been met.

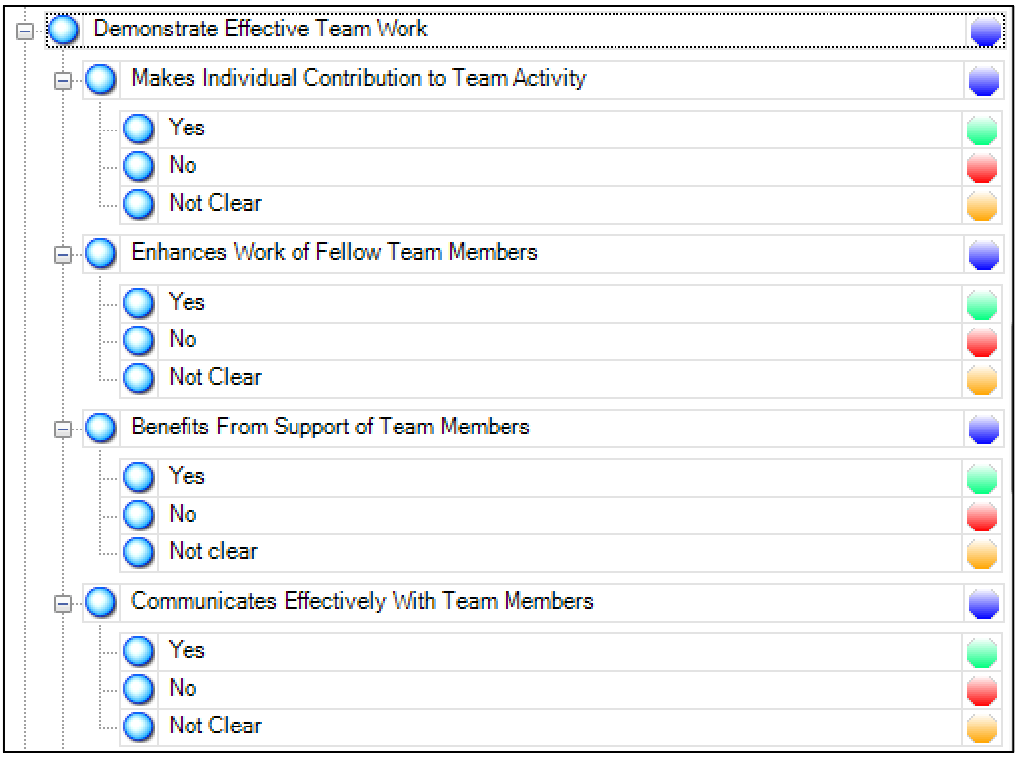


Figure 4-54: Child Nodes for Each ECSA Outcomes Level 8 Requirement

There were instances were no part of the reflection indicated or eluded to a requirement, so no coding could be done. Results will, therefore, be split into two groups: Percentage coded to indicate the outcome of the reflections compared with all other reflections that were coded, and then Percentage of Total, showing the results against the entire sample size.

Coded data was exported from NVivo into Excel, so that the any nodes that had been used for the same individual could be identified and reviewed so that the appropriate assessment of individual could be done. An example was Student X, who had been coded to meet both the requirements of not communicating effectively and then that effective communication was "Not Clear". The reflection was reviewed and coded accordingly. This was done to avoid any ambiguous or dual coding that might have occurred.

4.7.3 OVERALL RESULT FROM SAMPLE GROUP

All student reflections were measured against each ECSA ELO 8 requirement, the findings of which are to be discussed in the following sections.

PREAMBLE – CODED VERSUS POPULATION OF STUDENTS

Although effort was made to code each reflection with the ECSA ELO 8 requirements in mind of deductive analysis, there were instances where the reflection gave no suggestion or allusion to the student having met the requirements. Every requirement is, therefore, compared with the project sample size (all reflections given) and has been termed project sample. All results have also been compared separately to reflections where coding was achievable, and has been termed coded sample shown in Figure 4-56.

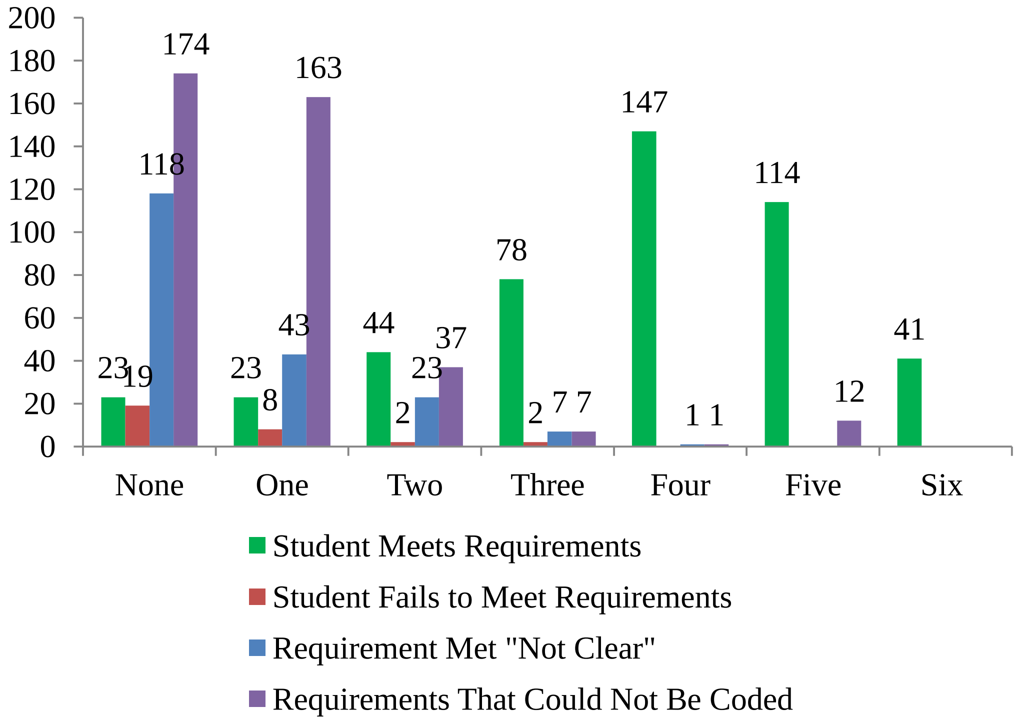


Figure 4-55: Summary of Overall Coded Data

Some reflections gave conflicting or ambiguous feedback, and it was not clear whether the student had met the requirements. The coded sample is, therefore, made up of Requirements Met, Requirements Not Met, or Requirement Met Not Clear. Many reflections failed to identify any form of the requirement, to the extent that no words, phrases, paragraphs, or whole passages could be pieced together to ascertain whether a requirement had been met. In short, lack of any expression made it impossible to code for the ECSA ELO 8 requirement using NVivo software.

4.7.4 Inference from Student Reflections' Coverage

A comparison is drawn by the sample code, the required sample size and the coverage of the population by the coded reflections.

Table 4-6: Inference of Students Reflections to the Student Population

ECSA ELO 8 Requirements	Coded Sample	Required Sample Size	Coverage of Population [%]
Benefits From Support of Team Members	420	384.16	89.36%
Communicates Effectively With Team Members	447	384.16	95.11%
Deliver Completed Work on Time	174	384.16	37.02%
Enhances Work of Fellow Team Members	397	384.16	84.47%
Makes Individual Contribution to Team Activity	415	384.16	88.30%
Performs Critical Functions	251	384.16	53.40%
Acquire a Working Knowledge of Co-Worker's Discipline	443	384.16	94.26%
Communicate Across Disciplinary Boundaries	442	384.16	94.04%
Use a Systems Approach	447	384.16	95.11%

The availability of coded sample is shown in Table 4.6 is shown out of the initial population held 470 reflections. The sample size requirement is calculated using Equation 1 to calculate a value of 384.16 as adequate representation. The coverage value is calculated by dividing the coded value by the initial population.

We may, therefore, infer that the coded reflections of students are considered to be representative of the population of students (95% Confidence). The ECSA ELO 8 requirements that may be considered met and represented as that of the population of students are:

- Communicates Effectively With Team Members
- Acquire a Working Knowledge of Co-Workers Functions
- Communicate Across Disciplinary Boundaries
- Use a Systems Approach

These outcomes will be explored further to identify whether the students have met the ECSA ELO 8 requirements, using the reflections given by students.

The ECSA ELO 8 requirements that did not allow for the inference of the population of students have been identified as two separate groups for further exploration:

1. The first group identified as not having any text within the reflection to code to

2. The second group to be explored further, as they meet the requirements of the suggested sample size.

4.7.5 REGRESSION OF SAMPLE DATA

Regression of the sample data is completed by the use of profiling.

PROFILES OF STUDENTS

Exploration of data is completed using both the dichotomous profile (Yes vs No) and the nominal profile. The coded data will be analysed using Minitab. Each ECSA ELO 8 requirement is to be explored individually, and in conjunction with one another. For this purpose, each requirement is assigned a value, whereby meeting the requirement i.e Yes is allocated a value of 1. Each negative response (No) is allocated a value of -1, and any ambiguous or contradictory reflection (Not Clear) is allocated a value of 0, so as to ensure that it is considered neutral and does not affect the overall score of the student. After each requirement is coded in this way, an overall score per student is found, indicating the level at which they had met the requirements.

It is apparent from the Table 3.14 that Student 1 had a positive experience with regard to the multidisciplinary area of work (according to their own perception or reflection, but was ambiguous and/or contradictory when reflecting on effective team work. It is to be noted that the students were not instructed to reflect using the ECSA ELO 8 requirements, so specific mention of each particular requirement is not expected. Student 3 reflected that he could not understand the terminology used by other students and did not feel that he learnt any new skills from the project. A systems approach was not easily identified and was, therefore, coded ‘Not Clear. It is easily identifiable that Student 3 experienced very few of the requirements, and as such, the percentage of ECSA ELO 8 requirements met is only at 11%. It is to be noted that some students may in fact have a negative percentage, if most of their perception of the project is negative.

4.7.6 Regression Analysis of Categorical Data/Predictors

Regression analysis is used to identify whether the suggested predictors are significant. Inherent categories as well as emergent categories and themes will be explored. Each ECSA ELO 8 requirement will, therefore, be analysed by the category identified, and will be compared to the ECSA Outcomes Yes, ECSA Outcomes No and % ECSA Outcomes Met.

It is important to remember that inherent categories come from the Literature Review and Pilot Studies, whereas emergent themes are deduced from the qualitative analysis.

Inherent Categories will include:

- The number of student members per group
- Year of Study
- Groups of Students/Focus Groups
- Case Study

Emergent themes will include:

- School
- Discipline

It is to be noted that the regression analysis is used for the full time period that the research presides upon, and is thus tested against the entire requirement of ECSA ELO 8. It is noted that some predictors may be significant with regard to particular ECSA ELO 8 requirements. All statistical calculations may be found in Appendix E. The categories or predictors have subdivisions and may be grouped as follows:

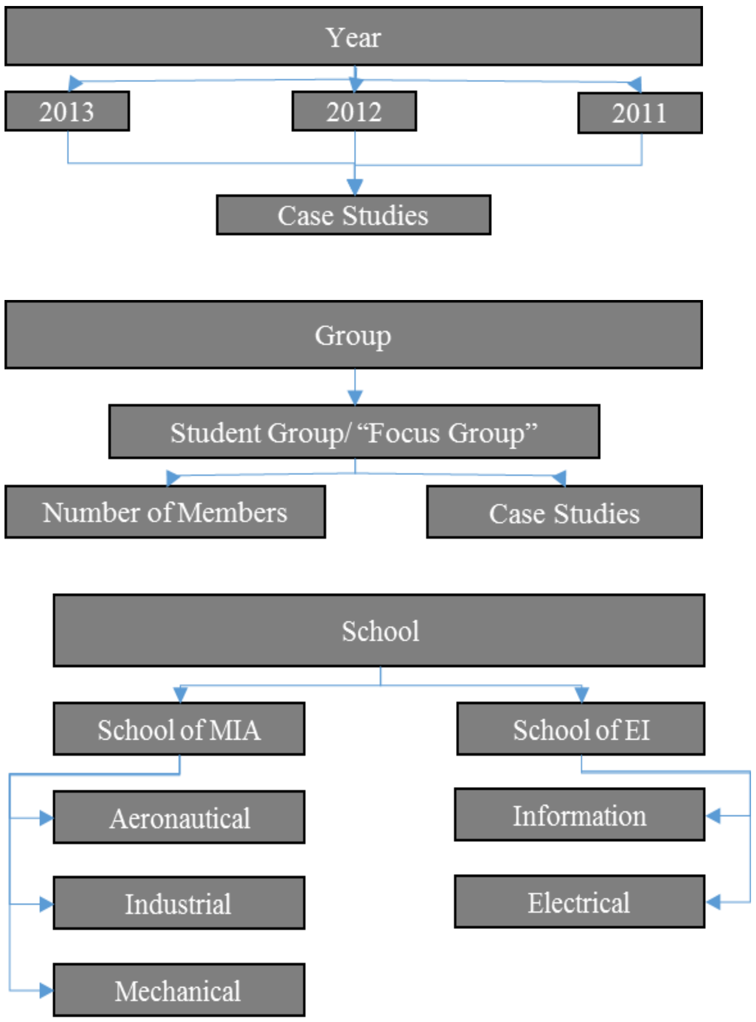


Figure 4-56: Categorical Data Groups (Predictors)

Predictor: Year

The regression analysis compared the correlation of the significance of the year to the ECSA ELO being met / Not Met. It was found that only Year 2013 was statistically significant in the student meeting the ECSA ELO 8 Outcomes, with α = 0.05.

Table 4-7: Regression Analysis by Year

Prediction Criteria	Year		
	2011	2012	2013
Significant to ECSA Outcomes Yes	No	No	Yes
Significant to ECSA Outcomes No	No	No	No
Significant to % ECSA Outcomes	No	No	No

The calculated p-value of 0.046 indicated that Year 2013 could be accounted for 0.64% of the increase in ECSA Outcomes being met. As a slight increase is noted, it is not expected that the increase be correlated with % ECSA Outcomes, which is a stringent control measurement. No other year proved significant in either the increase or decrease in the ECSA ELO 8 requirements being met.

PREDICTOR: CASE STUDY

c It was found that Case Studies C-5 Cargo Airlifter, Hubble, Theatre Battle Management |Core, F-111 Fighter and B-2 Bomber were statistically significant in the student meeting the ECSA ELO 8 Outcomes, with α = 0.05.

Table 4-8: Regression Analysis of Case Studies

Case Study	Response	C-5 Cargo Airlifter	Hubble	Theatre Battle Management Core	F-111 Fighter	B-2 Bomber
Outcomes Yes	Significant	Yes	Yes	Yes	Yes	No
	Correlation	Negative	Negative	Negative	Positive	
	p-value	p=0.023	p=0.033	p=0.037	p=0.024	
Outcomes No	Significant	Yes	Yes	No	No	Yes
	Correlation	Positive	Positive			Positive
	p-value	p=0.000	p=0.010			p=0.000
% ECSA Outcomes	Significant	Yes	Yes	No	Yes	Yes
	Correlation	Negative	Negative		Positive	Negative
	p-value	p=0.044	p=0.010		p=0.051	p=0.044

With the exception of the F-111 Fighter case study, all other mentioned case studies were found to have an adverse effect on the students' meeting the ECSA ELO 8 requirements. It is to be noted that most case studies that correlated negatively with Outcomes Yes are found to correlate positively with Outcomes No All case studies identified were confirmed using the stringent control % ECSA Outcomes, (barring the Theatre Battle Management Core).

All other case studies used during the three years were found to have an insignificant effect on the students' reflections of MECN4020. No further analysis on Case Studies will thus be performed.

PREDICTOR: STUDENT GROUP/FOCUS GROUP

Analysis of Means (ANOVA) was used to identify whether there were significant variation in the means of each focus group when comparing Outcomes Yes, Outcomes No and % ECSA Outcomes.

It was found that although there was some variance between groups, it was not significant except for groups B2_G10A, B2_G10B and HUB_G2B and R. The first three groups are noted as groups that selected the case studies identified as those adversely correlated with meeting the ECSA ELO 8 requirements. Group R may be explained using group formation dynamics. As there is no likelihood of repeating the group formation dynamics of this population, no further statistical analysis will be used.

PREDICTOR: NUMBER OF STUDENTS PER GROUP

The regression analysis compared the correlation of the significance of the number of students per group to the ECSA ELO being met / Not Met. The number of students per group is compared using ECSA Outcomes Yes and ECSA Outcomes No, and validated using ECSA % Outcomes, and yielded the following results:

Table 4-9: Regression Analysis of Number of Group Members

Prediction Criteria	Number of Group Members	
	Students x 4	Students x 5
Significant to ECSA Outcomes Yes	No	No
Significant to ECSA Outcomes No	Yes	Yes
Significant to % ECSA Outcomes	No	No

It was found that the ECSA ELO 8 requirements were not adversely affected by the reduction or inclusion of 1 x student member within a group. The incidence of both combinations of students as significant for ECSA Outcomes No is identified as discordant, as a general regression of number of students and ECSA Outcomes. No indicates no significant regression, indicating that the significance is due to other factors rather than group member numbers. A high level of multilinearity is noted.

PREDICTOR: SCHOOL

No correlation was found between ECSA ELO 8 requirements and different schools.

PREDICTOR: DISCIPLINE

The regression analysis compared the correlation of the significance of the number of students per group to the ECSA ELO being met / Not Met. It was found that only the Aeronautical Discipline had a correlation to the ECSA ELO 8 requirements.

Table 4-10: Regression Analysis of Discipline

ECSA ELO 8	Discipline	Aeronautical	Electrical	Industrial	Information	Mechanical
Outcome "Yes"	Significant	Yes	No	No	No	No
	Correlation	Positive	-	-	-	-
	p-value	p=0.029	-	-	-	-
Outcome "No"	Significant	Yes	No	No	No	No
	Correlation	Negative	-	-	-	-
	p-value	p=0.011	-	-	-	-
% ECSA Outcomes	Significant	Yes	No	No	No	No
	Correlation	Positive	-	-	-	-
	p-value	p=0.09	-	-	-	-

This was not the expected result, as emergent themes indicated that students had vastly different core competencies and opinions of other disciplines. The analysis has, however, been completed over the duration of three years, and further statistical analysis of each requirement per discipline will be explored. Binary regression analysis indicated that Aeronautical Engineering was not affected by year, and thus, neither year nor case study could be found significant (Appendix E).

4.7.7 HYPOTHESIS TESTING AND INFERENCE

A binomial inference test will be used to identify whether the amount of students that were coded as Yes – for that particular ECSA ELO 8 requirements.

Sample 1: The coded sample – Yes, Not Clear and No will use a point estimate to ascertain whether inference of the requirement met may be inferred to those students coded as Not Clear. A 95% Confidence level will be used.

Sample 2: The whole student sample of 470 students. A confidence level of 95% will be used. It is noted that Sample 2 will be referred to as the student population of the research hereafter, and should not be confused with the total population of students that will register for the course MECN 4020 in the future or past, but the students registered between Year 2011 and Year 2013 that qualified for the research based on the assumptions stated. All statistical calculations may be found in Appendix F.

The null hypothesis for both sample sets will test to whether the dataset may infer whether the student has met the ECSA ELO 8 requirements Not Clear and student population, respectively), and provide confidence intervals for each requirement.

$H_{1\text{-Individual}}$: MAKE INDIVIDUAL CONTRIBUTIONS TO THE TEAM ACTIVITY?

The coded reflections for this requirement were 415 reflections.

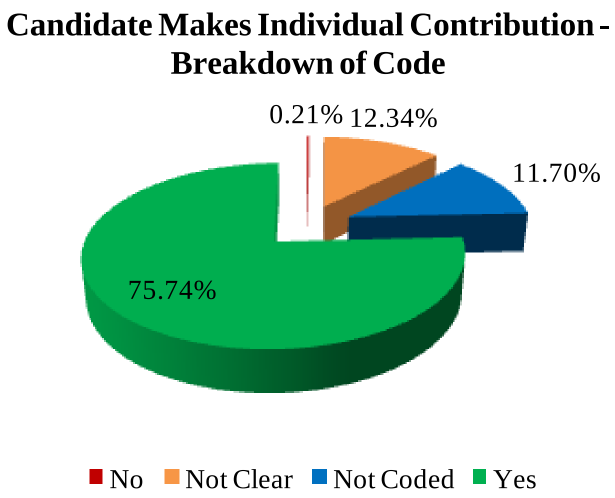


Figure 4-57: Population Results of Makes Individual Contribution

INFERENCE FOR NOT CLEAR

For the coded sample, 85.78% of students within the sample met the requirement of Makes Individual Contribution to Team Work, with a significant proportion giving an ambiguous or contradictory reflection (13.98%). A negligible number of students identified that they had not contributed individual contributions (0.24%).

The point estimate of the sample and maximum likelihood is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-IndividualContributionYes/No}} = H_{1\text{-IndividualContributionNotClear}}$

Alternative hypothesis $H_{1\text{- -IndividualContributionYes/No}} \neq H_{1\text{ IndividualContributionNotClear}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-11: Confidence Intervals for Makes Individual Contribution to Team

Wald Confidence Interval	(82.42%, 89.14%)
Wilsons Adjusted Confidence Interval	(82.06%, 88.81%)
Score Confidence Interval	(82.01%, 88.81%)

It is inferred that the sample is indicative of the Not Clear coded reflection of students, and that the Not Clear candidates meets the ECSA ELO 8 requirement Makes Individual Contribution (according to their experience) between 82.01% and 88.81% at a 95% Confidence Level.

Inference for Student Population

For the student population sample, 75.74% of students within the sample met the requirement of Makes Individual Contribution to Team Work, with 11.70% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-IndividualContributionYes}} = H_{1\text{-IndividualContributionPopulation}}$

Alternative hypothesis $H_{1\text{- -IndividualContributionYes}} \neq H_{1\text{ IndividualContributionPopulation}}$

It is inferred that the sample is indicative of the reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Makes Individual Contribution (according to their experience) at a 95% confidence level shown in the table below:

Table 4-12: Conclusion Inference for Individual Contribution of Candidate

Wald Confidence Interval	(71.69%, 79.62%)
Wilsons Adjusted Confidence Interval	(71.66%, 79.40%)
Score Confidence Interval	(71.67%, 79.40%)

4.7.8 $H_{1\text{-CRITICICALFUNCTIONS}}$: PERFORM CRITICAL FUNCTIONS?

The sample size (coded reflections) for this requirement was 251 reflections.

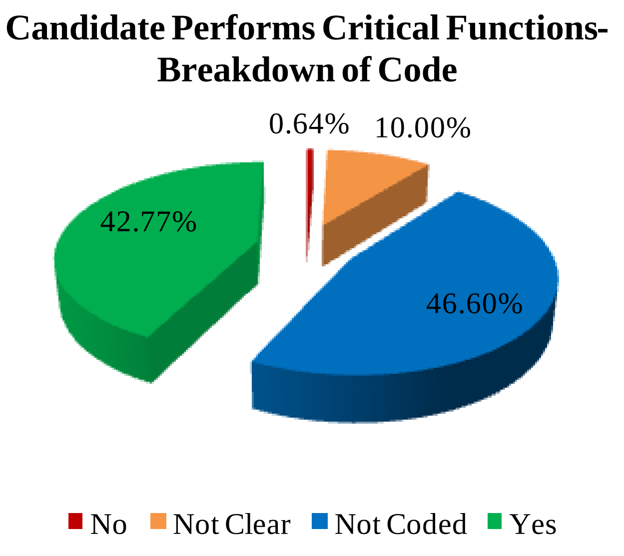


Figure 4-58: Population Results of Performs Critical Functions

INFERENCE OF NOT CLEAR

For the coded sample, 80.08% of students within the sample met the requirement of Performs Critical Functions, with a significant proportion giving an ambiguous or contradictory reflection (18.73%). A negligible number of students identified that they had not contributed individual contributions (1.20%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-CriticalFunctionYes/No}} = H_{1\text{CriticalFunctionNotClear}}$

Alternative hypothesis $H_{1\text{- -CriticalFunctionYes/No}} \neq _{\text{CriticalFunctionNotClear}}$

Inference to the Population of Students

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\ \text{CriticicalfunctionsSample}} = H_{1-\ \text{CriticicalfunctionsPopulation}}$

Alternative hypothesis: $H_{1-\ \text{CriticicalfunctionsSample}} \neq H_{1-\ \text{CriticicalfunctionsPopulation}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-13: Confidence Intervals for Performs Critical Functions for Not Clear

Wald Confidence Interval	(75.14%,75.14%)
Wilsons Adjusted Confidence Interval	(74.66%, 84.55%)
Score Confidence Interval	(74.70%, 84.55%)

It is inferred that the sample is indicative of the Not Clear coded reflection of students, and that the Not Clear candidate meets the ECSA ELO 8 requirement Performs Critical Functions (according to their experience) between 74.70% and 84.55 at a 95% Confidence Level.

Inference for Student Population

For the student population sample, 42.77% of students within the sample met the requirement of Performs Critical Functions, with 46.60% of students not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{1\ \text{CriticicalfunctionsYes}} = H_{1-\ \text{CriticicalfunctionsPopulation}}$

Alternative hypothesis: $H_{1-\ \text{CriticicalfunctionsYes}} \neq H_{1-\ \text{CriticicalfunctionsPopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement

Candidate Performs Critical Functions (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-14: Conclusion Inference for Student Performs Critical Functions

Wald Confidence Interval	(38.29%, 38.29%)
Wilsons Adjusted Confidence Interval	(38.37%, 47.28%)
Score Confidence Interval	(38.37%, 47.28%)

4.7.9 $H_{1\text{-}EMHANCE}$: ENHANCE WORK OF FELLOW TEAM MEMBERS?

The sample size (coded reflections) for this requirement was 397 reflections.

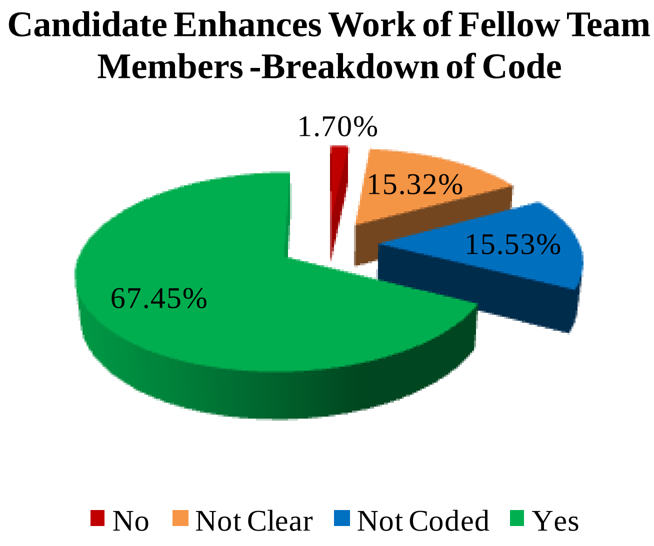


Figure 4-59: Population Results of Enhances Work of Fellow Team Members

INFERENCE FOR NOT CLEAR

It is calculated that 79.85% of coded students' reflections met the requirement of Enhances Work of Team Members, with a significant proportion giving an ambiguous or contradictory reflection (18.14%). A small number of students identified that they had not enhances the work of fellow team members (2.02%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-EhancesWorkYes/No}} = H_{1\text{EhancesWorkNotClear}}$

Alternative hypothesis $H_{1\text{- -EhancesWorkYes/No}} \neq {}_{\text{EhancesWorkNotClear}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-15: Confidence Intervals for Enhances Work of Team Members

Wald Confidence Interval	(75.90%, 75.90%)
Wilsons Adjusted Confidence Interval	(75.60%, 83.50%)
Score Confidence Interval	(75.60%, 83.50%)

It is inferred that the sample is indicative of the Not Clear coded reflection of students, and that the Not Clear candidates meet the ECSA ELO 8 requirement of Enhances Work of Team Members (according to their experience) between 75.60% and 83.50% at a 95% Confidence Level.

Inference for the Population

For the population of students, 67.45% of students within the sample met the requirement of Enhances Work of Team Members, with 15.53% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{ EnhancesWorkYes}} = H_{1\text{- EnhancesWorkPopulation}}$

Alternative hypothesis: $H_{1\text{- EnhancesWorkYes}} \neq H_{1\text{- EnhancesWorkPopulation}}$

It is inferred that the sample is indicative of the reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Enhances Work of Fellow Team Members (according to their experience) at a 95% confidence level, shown in the table below:

Table 4-16: Conclusion Inference for Student Enhances Work of Team Members

Wald Confidence Interval	(63.21%, 63.21%)
Wilsons Adjusted Confidence Interval	(63.08%, 71.52%)
Score Confidence Interval	(63.08%, 71.53%)

4.7.10 $H_{1\text{-BenefitsFromTeam}}$: Benefits From Support of Team Members?

The sample size (coded reflections) for this requirement was 420 reflections.

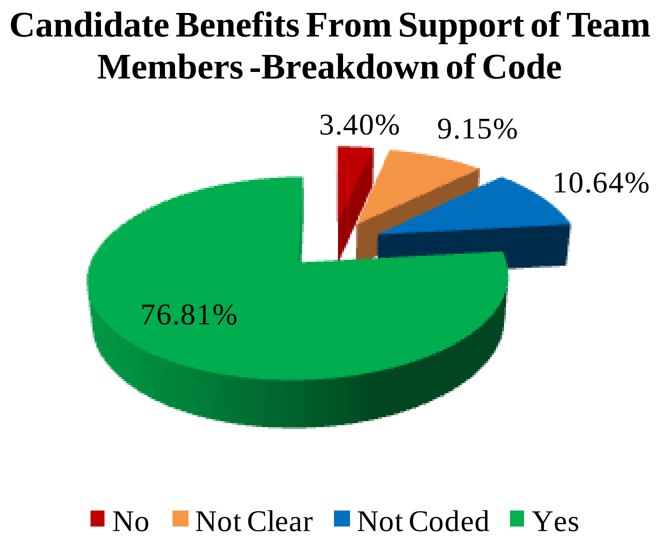


Figure 4-60: Population Results of Benefits from Support of Team Members

INFERENCE TO THE SAMPLE OF CODED STUDENTS

It is calculated that 85.95% of students within the sample met the requirement of Benefits From the Support of Team Members, with a significant proportion giving an ambiguous or contradictory reflection (10.24%). A sample number of students identified that they had not benefitted from their team members support (3.81%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-BenefitsFromTeamSample}} = H_{1\text{-BenefitsFromTeamPopulation}}$

Alternative hypothesis $H_{1\text{-BenefitsFromTeamSample}} \neq H_{1\text{-BenefitsFromTeamPopulation}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-17: Confidence Intervals for Benefits from Support of Team Members

Wald Confidence Interval	(82.63%, 82.63%)
Wilsons Adjusted Confidence Interval	(82.27%, 88.95%)
Score Confidence Interval	(82.30%, 88.95%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Benefits from Support of Team Members (according to their experience) between 82.30%% and 88.95% at a 95% Confidence Level.

Inference for Student Population

For the student population sample, 76.81% of students within the sample met the requirement of Benefits from Support of Team Members, with 10.64% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{1\text{ BenefitsFromYes}} = H_{1\text{- BenefitsFromPopulation}}$

Alternative hypothesis: $H_{1\text{- BenefitsFromYes}} \neq H_{1\text{- BenefitsFromPopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Benefits from Support of Team Members (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-18: Conclusion Inference for Student Benefits from Support of Team Members

Wald Confidence Interval	(72.99%, 80.62%)
Wilsons Adjusted Confidence Interval	(72.77%, 80.39%)
Score Confidence Interval	(72.78%, 80.40%)

4.7.11 $H_{1\text{-COMMUNICATION}}$: COMMUNICATE EFFECTIVELY WITH TEAM MEMBERS?

The sample size (coded reflections) for this requirement was 447 reflections.

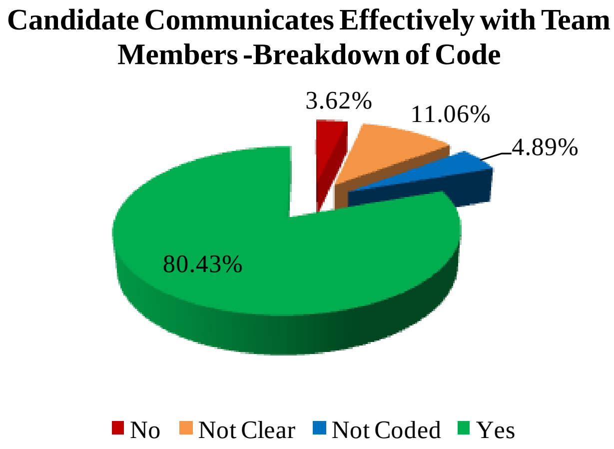


Figure 4-61: Population Results of Communicate Effectively of Team Members

INFERENCE TO THE SAMPLE OF CODED STUDENTS

It is calculated that 84.56 % of students within the sample met the requirement of Communicate Effectively with Team Members, with a significant proportion giving an ambiguous or contradictory reflection (11.63%). A sample number of students identified that they had not communicated effectively with team members (3.80%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-CommunicateEffectivelySample}} = H_{1\text{- CommunicateEffectivelySample Population}}$

Alternative hypothesis $H_{1\text{- CommunicateEffectivelySample}} \neq H_{1\text{- CommunicateEffectivelySample Population}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-19: Confidence Intervals for Communicates Effectively with Team Members

Wald Confidence Interval	(82.63%, 82.63%)
Wilsons Adjusted Confidence Interval	(82.27%, 88.95%)
Score Confidence Interval	(82.30%, 88.95%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Communicates Effectively with Team Members (according to their experience) between 82.30% and 88.95% at a 95% Confidence Level.

INFERENCE FOR STUDENT POPULATION

For the student population sample, 80.43% of students within the sample met the requirement of Communicates Effectively with Team Members, with 4.89% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{1\text{ Communicate EffectivelyYes}} = H_{1\text{-}} H_{1\text{ Communicate EffectivelyPopulation}}$

Alternative hypothesis: $H_{1\text{-}} H_{1\text{ Communicate Effectively}} \neq H_{1\text{-}} H_{1\text{ Communicate EffectivelyPopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Communicates Effectively with Team Members (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-20: Conclusion Inference for Student Communicates Effectively with Team Members

Wald Confidence Interval	(76.84%, 84.01%)
Wilsons Adjusted Confidence Interval	(76.58%, 83.76%)
Score Confidence Interval	(76.60%, 83.76%)

4.7.12 $H_{1\text{-COMMUNICATION}}$: DELIVER COMPLETED WORK ON TIME?

The sample size (coded reflections) for this requirement was 174 reflections.

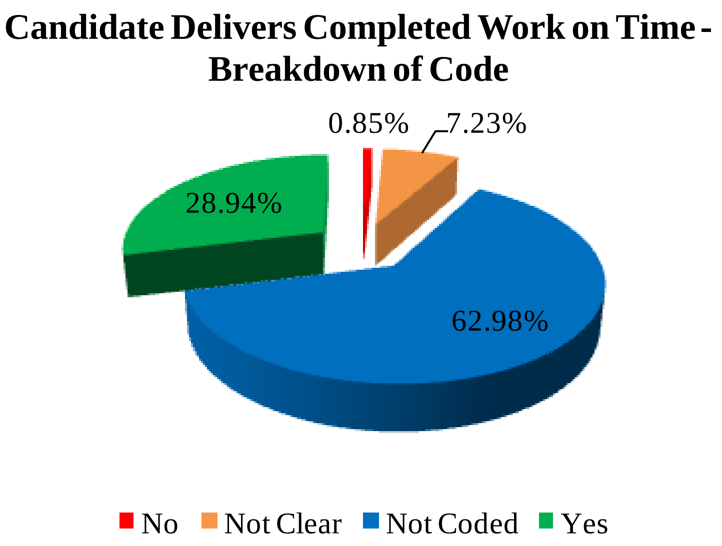


Figure 4-62: Population Results of Delivers Completed Work on Time

INFERENCE TO THE SAMPLE OF CODED STUDENTS

It is calculated that 78.16 % of students within the sample met the requirement of Deliver Completed Work on Time, with a significant proportion giving an ambiguous or contradictory reflection (19.14%). A sample number of students identified that they had not delivered completed work on time (2.02%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{1\text{-DeliverOnTimeSample}} = H_{1\text{- DeliverOnTimeSample Population}}$

Alternative hypothesis: $H_{1\text{-}}\,H_{1\text{ DeliverOnTimeSample}} \neq H_{1\text{-}}\,H_{1\text{ DeliverOnTimeSample Population}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-21: Confidence Intervals for Delivers Completed Work on Time

Wald Confidence Interval	(72.02%, 72.02%)
Wilsons Adjusted Confidence Interval	(71.39%, 83.66%)
Score Confidence Interval	(71.45%, 83.65%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Delivers Completed Work on Time (according to their experience) between 71.45% and 83.65% at a 95% Confidence Level.

Inference for Student Population

For the student population sample, 28.94% of students within the sample met the requirement of Delivers Completed Work on Time, with 62.98% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{1\text{ DeliverOnTimeYes}} = H_{1\text{-}}\,H_{1\text{ DeliverOnTimePopulation}}$

Alternative hypothesis: $H_{1\text{-}}\,H_{1\text{ DeliverOnTimeYes}} \neq H_{1\text{-}}\,H_{1\text{ DeliverOnTimePopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Delivers Completed Work on Time (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-22: Conclusion Inference for Student Communicates Effectively with Team Members

Wald Confidence Interval	(24.83%, 24.84%)
Wilsons Adjusted Confidence Interval	(25.02%, 33.20%)
Score Confidence Interval	(25.02%, 33.19%)

4.7.13 $H_{2\text{-WorkingKnowledge}}$: Acquire a Working Knowledge of a Co-Workers Discipline?

The sample size (coded reflections) for this requirement was 443 reflections.

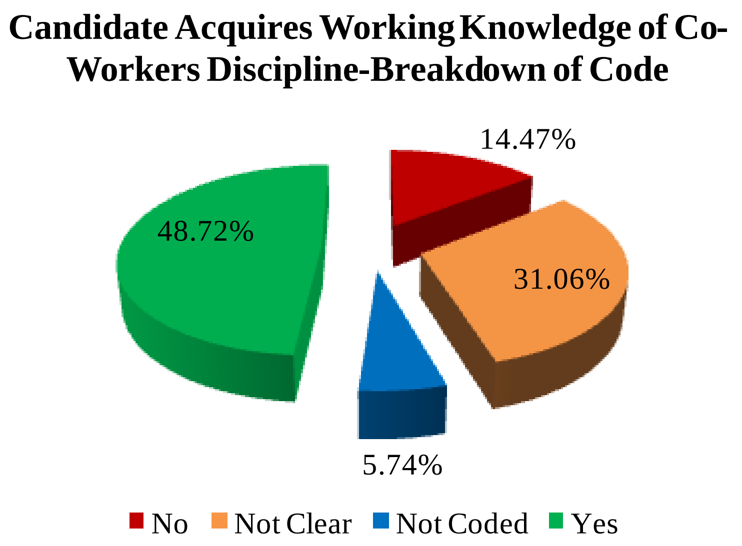


Figure 4-63: Population Results of Acquires a Working Knowledge of Co-Workers Discipline

Inference to the Sample of Coded Students

It is calculated that 51.69 % of students within the sample met the requirement of Acquire a Working Knowledge of a Co-Worker's Discipline, with a significant proportion giving an ambiguous or contradictory reflection (32.96%). A sample number of students identified that they had not acquired a working knowledge of a co-workers discipline (15.35%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{\text{-2-AcquireKnowledgeSample}} = H_{\text{2- AcquireKnowledgeSample Population}}$

Alternative hypothesis $H_{\text{2AcquireKnowledgSample}} \neq H_{\text{2- AcquireKnowledgSample Population}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-23: Confidence Intervals for Acquire a Working Knowledge

Wald Confidence Interval	(47.04%, 47.04%)
Wilsons Adjusted Confidence Interval	(47.05%, 56.31%)
Score Confidence Interval	(47.04%, 56.31%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Acquires a Working Knowledge of a Co-Workers Discipline (according to their experience) between 47.04% and 56.31% at a 95% Confidence Level.

INFERENCE FOR STUDENT POPULATION

For the student population sample, 48.72% of students within the sample met the requirement of Acquires a Working Knowledge of a Co-Workers Discipline, with 5.74% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{\text{2 Working KnowledgeYes}} = H_{\text{2 Working KnowledgePopulation}}$

Alternative hypothesis: $_{-} H_{\text{2 Working KnowledgeYes}} \neq H_{\text{2 Working KnowledgePopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement

Candidate Acquires a Working Knowledge of Co-Workers Discipline (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-24: Conclusion Inference for Student Acquires Working Knowledge of Co-Workers Discipline

Wald Confidence Interval	(44.20%, 53.24%)
Wilsons Adjusted Confidence Interval	(44.23%, 53.23%)
Score Confidence Interval	(44.23%, 53.23%)

4.7.14 $H_{2\text{-BOUNDARY}}$: COMMUNICATE ACROSS A DISCIPLINARY BOUNDARY

The sample size (coded reflections) for this requirement was 442 reflections.

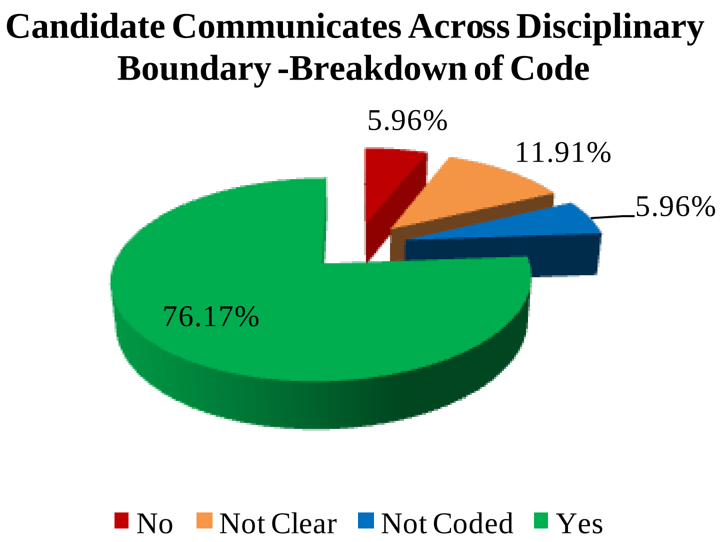


Figure 4-64: Population Results of Communicate Across a Disciplinary Boundary

INFERENCE TO THE SAMPLE OF CODED STUDENTS

It is calculated that 81.00 % of students within the sample met the requirement of Communicate across a Disciplinary Boundary, with a significant proportion giving an ambiguous or contradictory reflection (12.67%). A sample number of students identified that they had not (6.33%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{2\text{-BoundarySample}} = H_{2\text{-BoundarySample Population}}$

Alternative hypothesis $H_{2\text{-BoundarySample}} \neq H_{2\text{-BoundarySample Population}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-25: Confidence Intervals for Communicates Across a Disciplinary Boundary

Wald Confidence Interval	(77.33%, 84.65%)
Wilsons Adjusted Confidence Interval	(77.06%, 84.38%)
Score Confidence Interval	(77.08%, 84.38%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Communicate across a Disciplinary Boundary (according to their experience) between 77.08%% and 84.38% at a 95% Confidence Level.

INFERENCE FOR STUDENT POPULATION

For the student population sample, 76.16%% of students within the sample met the requirement of Communicates across a Disciplinary Boundary, with 5.96% not coded. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{2BoundaryYes} = H_{2BoundaryPopulation}$

Alternative hypothesis: $H_{2BoundaryYes} \neq H_{2BoundaryPopulation}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement Communicate across a Disciplinary Boundary (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-26: Conclusion Inference for Student Communicates Across Disciplinary Boundary

Wald Confidence Interval	(72.31%, 80.02%)
Wilsons Adjusted Confidence Interval	(72.10%, 79.80%)
Score Confidence Interval	(72.12%, 79.80%)

4.7.15 $H_{2\text{-}SYSTEMS}$: USE A SYSTEMS APPROACH?

The sample size (coded reflections) for this requirement was 447 reflections.

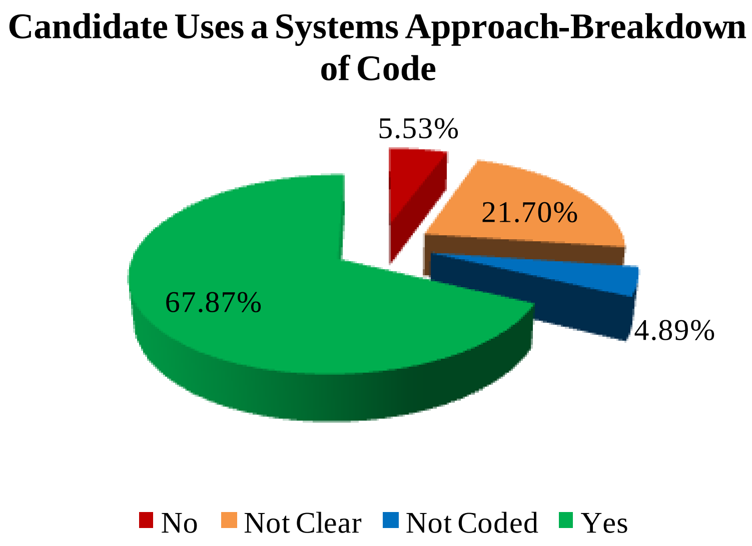


Figure 4-65: Population Results of Uses a Systems Approach

INFERENCE TO THE SAMPLE OF CODED STUDENTS

It is calculated that 71.36 % of students within the sample met the requirement of Use a Systems Approach, with a significant proportion giving an ambiguous or contradictory reflection (22.82%). A sample number of students identified that they had not (5.82%).

The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for inference are tested, and Confidence Intervals are identified at several levels.

Null hypothesis: $H_{2\text{-SystemSample}} = H_{2\text{-SystemSample Population}}$

Alternative hypothesis $H_{2\text{-SystemSample}} \neq H_{2\text{-SystemSample Population}}$

All assumptions were tested for, and the critical values identified along several levels. The confidence Intervals are represented below:

Table 4-27: Confidence Intervals for Uses a Systems Approach

Wald Confidence Interval	(67.17%, 75.56%)
Wilsons Adjusted Confidence Interval	(66.99%, 75.56%)
Score Confidence Interval	(67.01%, 75.36%)

It is inferred that the sample is indicative of the population of students, and that the candidate meets the ECSA ELO 8 requirement Use a Systems Approach (according to their experience) between 67.01% and 75.36% at a 95% Confidence Level.

Inference for Student Population

For the student population sample, 67.87% of students within the sample met the requirement of Uses a Systems Approach. The point estimate of the sample is used to calculate the standard deviation or error of the sample. Assumptions for the inference are tested, and confidence intervals are identified at several levels.

Null hypothesis: $H_{2\text{-SystemYes}} = H_{2\text{-SystemPopulation}}$

Alternative hypothesis: $H_{2\text{-SystemYes}} \neq H_{2\text{-SystemPopulation}}$

It is inferred that the sample is indicative of the population of reflection of the student population, and that the students meet the ECSA ELO 8 requirement Candidate Uses Systems Approach (according to their experience) at a 95% confidence interval, shown in the table below:

Table 4-28: Conclusion Inference for Student Uses Systems Approach

Wald Confidence Interval	(63.65%, 72.09%)
Wilsons Adjusted Confidence Interval	(63.51%, 71.93%)
Score Confidence Interval	(63.52%, 71.93%)

4.8 Summarised Inferences

A comparison of the inference for the Unclear and student population is compared, yielding the following results:

Table 4-29: Comparison of Sample and Population Inference

ECSA ELO 8 Requirements	Lower Confidence Limit for Sample	Lower Confidence Limit for Sample	Difference Between Confidence Intervals
Makes Individual Contribution to Team Activity	82.01%	71.67%	10%
Performs Critical Functions	74.70%	38.32%	36%
Enhances Work of Fellow Team Members	75.60%	63.08%	13%
Benefits From Support of Team Members	82.30%	72.78%	10%
Communicates Effectively With Team Members	82.30%	76.60%	6%
Deliver Completed Work on Time	71.45%	25.05%	46%
Acquire a Working Knowledge of Co-Worker's Discipline	47.04%	44.23%	3%
Communicate Across Disciplinary Boundaries	77.08%	72.12%	5%
Use a Systems Approach	67.01%	63.52%	3%

The Lower Confidence rates were calculated using a 95% Score confidence interval boundary. The difference in inference for the sample and the student population is seen as important, as a large difference is indicative of reflections where the student did not provide context for the coding of a particular ECSA ELO 8 requirement. It is noted that the two requirements that were largely affected were Performs Critical Functions and Delivers Completed Work on Time.

4.9 Inference Testing Per Predictor

The predictors identified by regression analysis are as follows:

- Year
- Discipline

4.9.1 Changes Made: Systems Management and Engineering Course

In response to the pilot study conducted (Sunjka 2011b), several changes were made to the subject, both in terms of context and deliverables. The following table outlines the changes made:

Table 4-30: Comparison of Instruction for Students' Reflection

Year	Instruction to Students
2011	• As a group and as individuals, reflect on the experience of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc. • Based on your reflections, each group member is to write about 300 words on their own individual experience of working in an inter-disciplinary group. These should be included in the appendices of your written report. You will receive an individual mark for this.

2012	• As individuals, reflect on the experience of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc. • Based on your reflections, each group member is to write about 300 words on their own individual experience of working in an inter-disciplinary group. These should be included in the appendices of your written report. You will receive an individual mark for this (10% of your final assignment mark).
2013	As individuals: Reflect on the experience of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc. Based on your reflections, write about 300 words on their own individual experience of working in an inter-disciplinary group. You will receive an individual mark for this (10% of your final project mark). Complete the confidential group member assessments (submit with your reflection)

The above table is taken verbatim from the subject hand-outs. It is seen that none of the leading questions prompting the students' reflections are changed. Other changes are noted:

- The requirement for a group reflection in the year 2011
- The stipulation of the mark allocation for the individual reflection for year 2012 and 2013
- The requirement to complete a confidential group member assessment with the student's individual reflection in the year 2013.

Further changes have also been noted throughout the three-year period:

Table 4-31: Changes in Project Deliverables per Year

Deliverable			
Requirement	Year 2011	Year 2012	Year 2013
Examination	X	X	X
Project Report	X	X	X
Presentation	X	-	-
Individual Reflection	X	X	X
Group Reflection	X	-	-

It is expected that students will identify more with the group dynamic than with individual endeavours, when comparing year 2011 to 2012 and 2013 respectively.

Table 4-32: Changes in Assessment Weighting Per Year

Assessment Rating			
Breakdown of Marks Allocated	Year 2011	Year 2012	Year 2013
Examination	50%	50%	50%
Assignment Mark	50%	50%	50%
Group Project Report	22.50%	30%	32.50%
Reflection	2.50%	5%	5%
Presentation Due	25%	0%	0%
Individual Assignment	Not Specified	10%	12.50%
Communication of Project	0%	5%	Not Specified
Communication Overall Rating	10%	10%	Not Specified

The assessment weighting is the only instance where all three years differ. It is expected that communication across a disciplinary boundary is improved with the presentation and hefty weighting thereof in year 2011. Individual contributions and critical functions are expected to improve from year 2012 to year 2013, due to the increased focus and weighting on individual assignments. Effective team work is also expected to improve slightly from year 2011, to year 2012 and then to year 2013 respectively.

Table 4-33: Changes in Time Frames per Year

Project Variables			
Time	Year 2011	Year 2012	Year 2013
Hand-out Date	21-Feb	11-Feb	11-Feb
Project Document Done	06-Jun	21-May	10-May
Project Days	76	71	65
Case Studies	12	2	2

It is not certain whether changes will be seen across years due to reduced times allocated for project completion, as deliverables had been reduced from year 2011 when compared to year 2012 and year 2013. The reduction in case studies aligns with the reduction in SACA Engineering Weighting. A comparison between year 2011 and year 2012 may indicate a change in whether the project was delivered in time.

All restrictions considering the combination of engineering disciplines has remained constant throughout the three year period, and no changes are expected from these restrictions.

The Yes responses to each ECSA ELO 8 requirement were compared by year, and yielded the following:

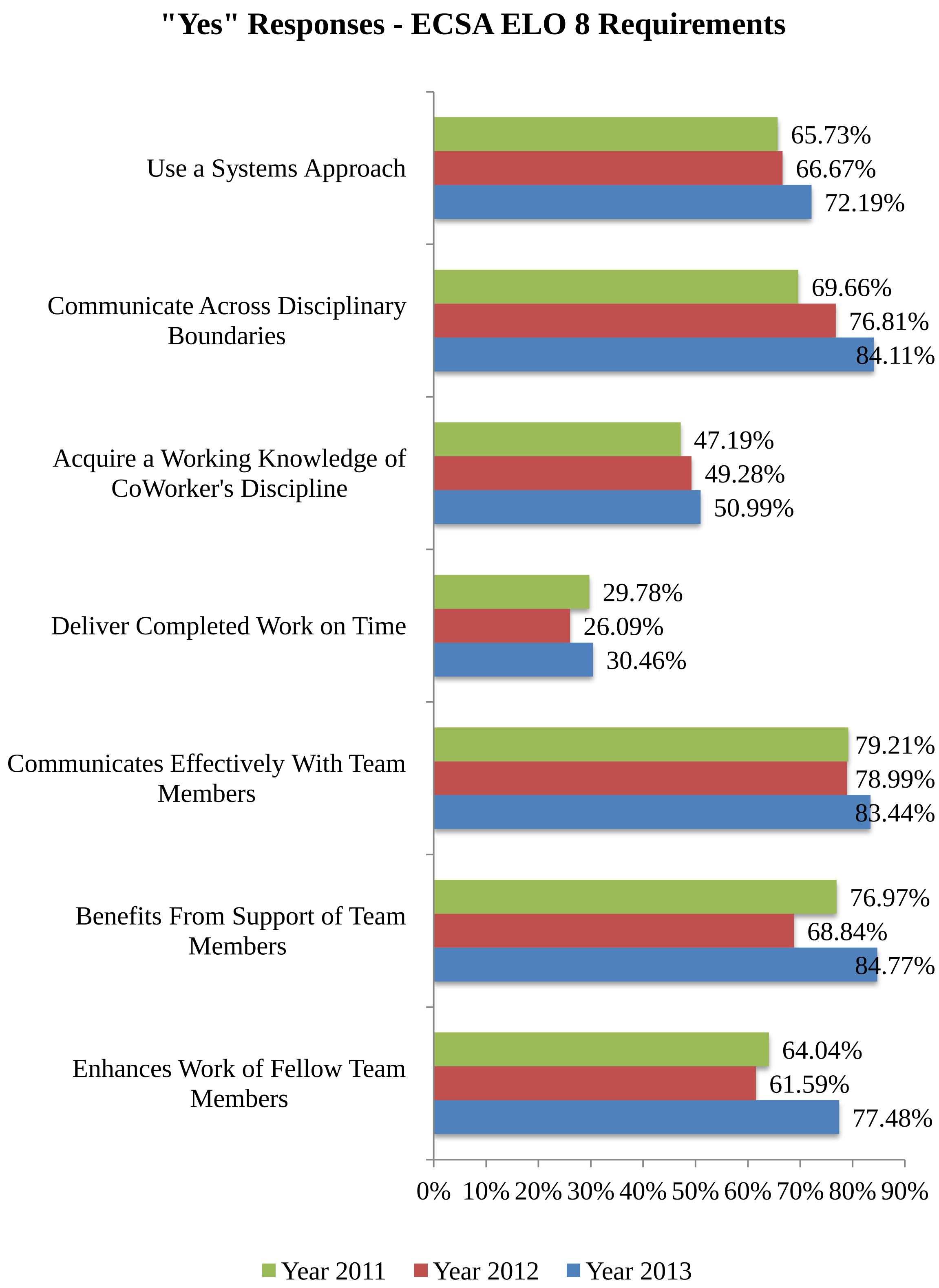


Figure 4-66: Comparison of ECSA ELO 8 Requirements and Yes Responses per Year

Figure 4-66 would indicate that there is a marked improvement overall, but it is noted that these are based sorely upon coded responses. Creating a Score Interval for each requirement per year, the confidence intervals for each requirement per year are inferred:

Table 4-34: Confidence Intervals of Inference per Year

Confidence Interval	Lower			Upper		
Year	2013	2012	2011	2013	2012	2011
Makes Individual Contribution to Team Activity [%]	68.77	66.01	69.65	82.25	80.52	82.04
Performs Critical Functions [%]	29.79	40.36	35.66	45.02	56.82	50.04
Enhances Work of Team Fellow Members [%]	70.19	53.27	56.77	83.42	69.29	70.73
Benefits From Support of Team Members [%]	78.18	60.69	70.25	89.63	75.9	82.54
Communicates Effectively with Team Members [%]	76.7	71.45	72.67	88.53	84.95	84.53
Delivers Completed Work on Time [%]	23.68	19.48	23.54	38.21	33.99	36.86
Acquires a Working Knowledge of Co-Workers Discipline [%]	43.09	41.07	39.99	58.84	57.52	54.51
Communicates Across Disciplinary Boundaries [%]	77.44	69.1	62.55	89.08	83.07	75.94
Uses Systems Approach [%]	64.56	58.44	58.49	78.71	73.99	72.3
Product Score [%]	0.44	0.2	0.25	3.86	2.46	2.24

As suggested by the regression analysis (Table 4-34), Year 2013 is seen as the most successful year, with the upper and lower confidence levels significantly higher than the previous years. This will be addressed in the discussion section (Section 5). Overall, it is seen that Year 2011 was considered as superior to Year 2012 by the reflections of students, but this may vary between disciplines or schools.

4.9.2 COMPARISON BY SCHOOL

The maximum likelihood is calculated for each ECSA ELO 8 requirement, and a 2 Sample t-test is used to ascertain whether there is a significant difference in means, and a standard deviance test to identify the difference in variance and between the maximum likelihoods for the ECSA Requirements per school (Minitab calculation in Appendix G).

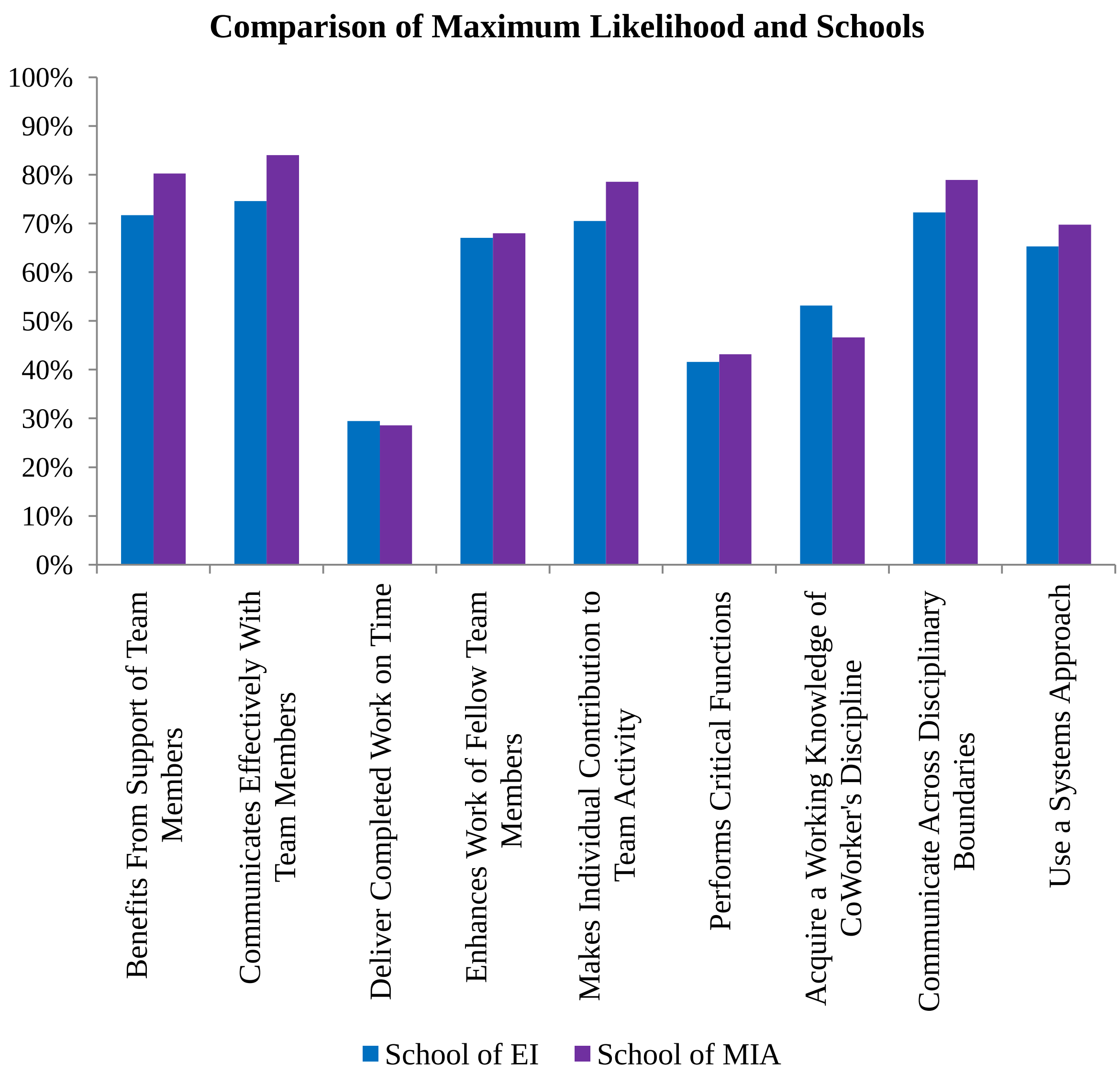


Figure 4-67: Difference in Maximum Likelihood of Schools

Statistically, there is no difference in either the means or variance between the two schools) at a 95% Confidence) (Appendix F). The differences between disciplines are considered next.

4.9.3 DIFFERENCE IN DISCIPLINES

Each discipline's maximum likelihood per ECSA ELO 8 requirement is calculated, and may be compared visually.

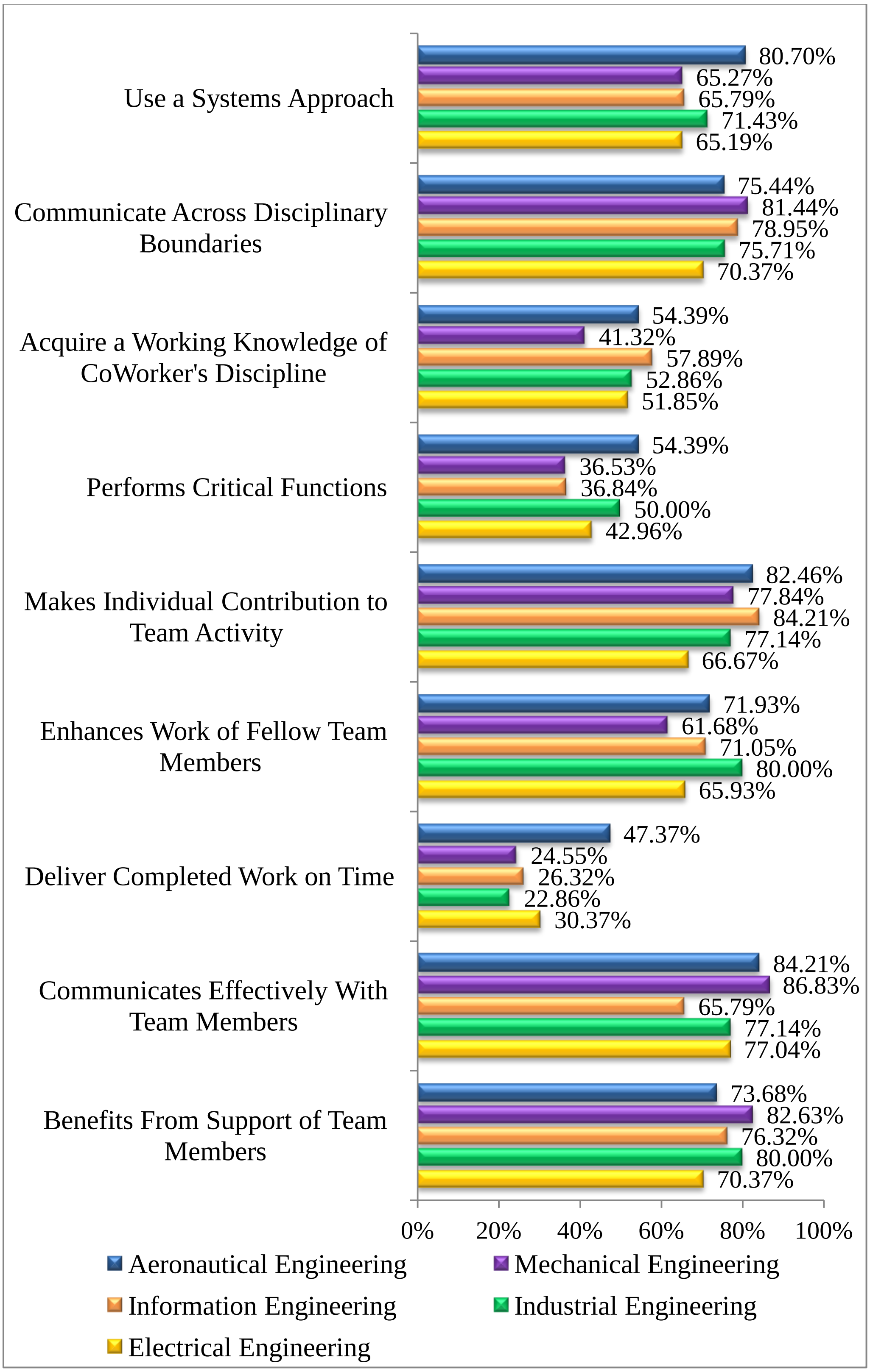


Figure 4-68: Comparison of Maximum Likelihood per Discipline

A one-way ANOVA test was completed, and it was found that the means between each discipline did not vary significantly (Minitab Calculation in Appendix G). A standard deviations test was completed, and it was found that the difference in variation per discipline did not vary (Minitab Calculation in Appendix G).

Aeronautical Engineering was found to be to be significantly different to the other branches in the regression analysis. For this reason, disciplines will be compared by year. Binary analysis of the Aeronautical Engineering Discipline was compared per year, and was found not to be statistically significant (Appendix G).

Disciplines Per Year

A one way ANOVA test was conducted for each year, and no year showed significant changes per discipline. There was no indicated discipline that is statistically different for Year 2011, Year 2012 and Year 2013.

Disciplines Per Criteria

Each discipline was compared per ECSA ELO 8 requirements, using a one-way ANOVA test, to ascertain whether there were differences between disciplines.

There were several instances were disciplines were found to have no effect on the ECSA ELO 8 Outcomes at a 95% significance level. It was found that the Electrical Engineering discipline gave a significantly lower reflection of Makes Individual Contribution to Team, Mechanical Engineering discipline a significantly higher reflection of Communicates Effectively with Team Members, and the Aeronautical Engineering Students a significantly higher response to Delivers Completed Work on Time.

There are several instances where no particular discipline crosses the Confidence Interval boundary, but that there is a clear display of a particular discipline coming exceptionally close to the boundary. Note of these occurrences have been made, as the sample sizes of some disciplines are small, and a 95% confidence was used. The significance level was, therefore, varied to identify the exact confidence with which each requirement was significant per discipline.

Table 4-35: Significance of Discipline Per ECSA ELO 8 Requirement

ECSA ELO 8 Requirement	Significance Level	Outcome of One-Way ANOVA
Makes Individual Contribution to Team Activity	95%	Electrical Engineering over negative boundary
Performs Critical Functions	81%	Aeronautical Engineering near positive boundary, Mechanical Engineering near negative boundary
Enhances Work of Fellow Team Members	92%	Industrial Engineering near positive boundary, Mechanical Engineering near negative boundary
Benefits From Support of Team Members	88%	Electrical Engineering near negative boundary, Mechanical Engineering near positive boundary
Communicates Effectively With Team Members	95%	Mechanical Engineering over positive boundary
Deliver Completed Work on Time	95%	Aeronautical Engineering over positive boundary
Acquire a Working Knowledge of CoWorker's Discipline	92%	Mechanical Engineering near negative boundary

Communicate Across Disciplinary Boundaries	80%	Mechanical Engineering near positive near boundary
Use a Systems Approach	87%	Aeronautical Engineering near positive boundary

5 DISCUSSION AND FINDINGS

This chapter begins by discussing the ambiguity that exists between the theoretical understanding of a Systems Approach and Cross-Disciplinary work with the ECSA ELO 8 requirements and MECN4020 project requirements. ECSA ELO 8 requirements with low inferences and maximum likelihoods are then identified, and extant literature and emergent themes used to substantiate the understanding thereof. Changes made to the course are explored, and identified predictors and extant literature used to identify whether any changes should be made to the course.

The ECSA ELO 8 requirements are then discussed in light of the emergent core competencies of each discipline where a relative significance is found.

5.1 Concerns: The Understanding of Systems Approach and Processing

The systems approach as identified by INCOSE requires that technological and non-technological aspects of the system be analysed, including social-psychological and economic aspect systems. It is differentiated from the piecemeal approach in that all aspect systems are well integrated and not chaotic. The current MECN4020 includes the economic aspect system, but does not entail the use of social-psychological aspect systems.

The ECSA ELO 8 requirements are found to require both effective team work as well as multidisciplinary work. However, when one examines the requirements for effective team work, it is found that the requirements met are those of multidisciplinary study. Multidisciplinary study is identified as that of involving several disciplines to the study of one topic, with each team member approaching the topic from their own skills and expertise. The requirements Make Individual Contributions to Team Activity, Perform Critical Functions and Communicate Effectively with Team Members speak directly to multidisciplinary work. The requirements Deliver Completed Work on Time is seen as a requirement for Project Management. The two other requirements, Benefit from the Support of

Team Members and Enhance the Work of Fellow Team Members may be seen as Project Management requirements (if they are meant to be interpreted as purely administrational), but may also be considered as interdisciplinary study requirements, if the benefit and enhancement of the individual is from a theoretical approach, requiring the integration of knowledge from other team members. The difference between the two requirements is based in the processing of information, with the former that of syntactic/information processing, and the latter that of semantic or pragmatic processing. This also creates the distinction of the piecemeal approach versus the systems approach.

The ECSA ELO 8 requirements for multidisciplinary are those of Communicate across a Disciplinary Boundary, Use a Systems Approach and Acquire a Working Knowledge of a Co-Workers Discipline. Communication across a disciplinary boundary may be construed as purely syntactic, where individuals are privy to the same lexicons and common knowledge. However, ECSA requires that students use a Systems Approach, which is transient in both interdisciplinary and multidisciplinary work. Furthermore, the systems approach given by INCOSE requires that students work from an Interdisciplinary or transdiciplinary approach, as the piecemeal approach is not seen as Systems Engineering. For the students to use a purely Systems Approach, and not a piecemeal approach, it is required that pragmatic processing take place, whereby the students transform their understanding of the project to another discipline. This sentiment is echoed by the requirement of Acquire a Working Knowledge of a Co-Workers discipline, which leans heavily on multidisciplinary or transdisciplinary work. Literature available does not necessarily align to the ECSA ELO 8 requirements for multidisciplinary.

The current project for MECN4020 requires multidisciplinary work, as students are required to perform their own individual analysis, and then to create common plan together, rather than integrate their individual analysis. This is expressed explicitly be the lecturer, who indicates that the ‘rehash’ of individual analysis is not allowed.

5.2 ECSA ELO 8 Requirements with Low Inference/ Maximum Likelihood

The ECSA ELO 8 requirements that were identified as having a low inference/maximum likelihood for the student group are Performs Critical Functions (38.37%) and Delivers Completed Work on Time (25.02%). This is not to say that the students did not meet the requirements, but rather that the students reflected on differences between disciplines, difficulties and the actions required to overcome these difficulties, as lead by the lecturers' reflection criteria. If it is considered as not feasible to request that the students reflect on the actual ECSA ELO 8 requirements, it is recommended that students also reflect on the strengths of their own disciplines (Perform Critical Functions) and reflect on the outcome or completion of the project (Delivers Completed Work on Time), as the inference and maximum likelihood were heavily affected by reflections that had no words, phrases, or paragraphs to code accordingly (Not Coded).

Other ECSA ELO 8 requirements that were found to have low inference and maximum likelihoods were Acquire a Working Knowledge of a Co-Workers Discipline (44.23%) and Use a Systems Approach (67.01%). The reflections of the students were either ambiguous and/or contradictory in this regard (Not Clear), indicating that the students used syntactic processing and the piecemeal approach respectively. Great care has been taken by the lecturer to avoid both syntactic processing and the piecemeal approach by requiring that each student perform their own individual short-cycle and long-cycle analysis. However, in many reflections, the students were rushed into a final solution because of time constraints and/or frustrations, resulting in the group members being pushed toward integration, without building rapport and exploring ways to understand how each discipline approaches the project, resulting in reduced to multidisciplinary. This is further bolstered by the higher inference and maximum likelihoods of Communicates Across a Disciplinary Boundary (72.17%), indicating that students initially used interdisciplinary work and pragmatic processing, but that the final act of interdisciplinary integration of work is lost due to lack of continued communication across a disciplinary boundary. The group formation dynamic follows that of the cyclical transforming phase, rather than the storming-norming-performing phase. This results in the failure of the students to gain the necessary competence and communication base over time, as well as the loss of empowerment of students (Acquire a Working Knowledge of a Co-Workers Discipline) in one other discipline. Multidisciplinary work, (from a theoretical standpoint) is, however, achieved.

5.2.1 THE COMPARISON OF ECSA ELO 8 INFERENCE WITH OTHER TERTIARY OUTCOMES

It was found that students reflected poorly in the ECSA ELO 8 requirements Performs Critical Functions and Delivers Completed Work on Time due to omission, and Acquires a Working Knowledge of a Co-Worker's Discipline and Uses a Systems Approach due to ambiguous and/or contradictory reflection. Communicating across a Disciplinary Boundary was found to occur initially, but tapered off as the course progressed. The extant literature identified that the students from CPSU did not improve significantly in areas such as evaluating evidence and information about environmental issues, implementing strategies, and working with others from different backgrounds to pose and evaluate resolutions to complex problems.

The similarity of the results indicate that the communication across a disciplinary boundary is seen as pivotal if a systems approach and the acquirement of a working knowledge of another discipline are to be achieved. This may only be achieved through semantic and pragmatic processing continuously and consistently applied, throughout the project's progression, and not just as an initial measure.

5.3 Changes Made to Course MECN4020

Myriad changes to the project of MECN4020 have been made, and the predictors identified.

5.3.1 PREDICTOR: YEAR

Year 2013 is identified as the most successful year, with an improvement seen in the inference and maximum likelihood of all ECSA ELO 8 requirements, barring

Performs Critical Functions. Although the correlation was found as positive in meeting the ECSA ELO 8 requirements (0.64%), it does not imply causation. As Performs Critical Functions was identified as a requirement, where the students did not reflect on specifically (Not Coded), it is re-stated that the students should be requested to identify their own discipline's strengths.

5.3.2 PREDICTOR: CASE STUDY

Four case studies were found to correlate negatively with the ECSA ELO 8 requirements being met, namely C-5 Cargo Airlifter, Hubble Space Telescope, Theatre Battle Management Core and B-2 Bomber. The only case study that correlated positively with the ECSA ELO 8 requirements being met was the F111-Fighter. As all of the aforementioned case studies are no longer being used, the changes to the case studies made by the lecturer is seen as positive.

5.3.3 PREDICTOR: NUMBER OF STUDENTS PER GROUP

A correlation between the ECSA ELO 8 requirements not being met and 5 group members was found. However, due to the level of multilinearity within the regression, the researcher has found that the number of group members is not statistically significant to meeting the ECSA ELO 8 requirements. It should, however, be noted that a correlation between number of students in the group and *not* meeting the ECSA ELO 8 requirements was statistically significant, and that the students' reflections indicated that the reduction in number of group members adversely affected the response of the student, as the student felt as if it had impacted their ability to perform.

5.4 Differences in Discipline per ECSA requirement:

The lecturer requested that each student reflect on how working with different disciplines impacted the student's ability to learn and understand. Each discipline was tested against the other using Analysis of Means, and the researcher was able to identify particular disciplines of engineering that had an overtly positive or negative reflection for each ECSA ELO 8 requirement. Any ECSA ELO 8 requirement with a significance level of 90% will be discussed due to the large difference in the sample sizes of each discipline.

It is noted that the Aeronautical Engineering Discipline was the only discipline that was statistically significant in the regression analysis of the ECSA ELO 8 requirements being met, when the reflections from all three years were tested. The adjusted correlation of 0.80% is low, and does not suggest that the Aeronautical Engineering Discipline has a causal effect.

5.4.1 THE CANDIDATE MAKES AN INDIVIDUAL CONTRIBUTION TO TEAM ACTIVITY

It was found that the Electrical Engineering discipline was considered an outlier for Makes Individual Contribution to Team Activity (95% Confidence Level) when compared to the other disciplines. The relatively negative reflection is understandable when emergent themes are reflected upon. The students described that the Electrical Engineers' core competency is that of Detailed Assistance in Software and Leadership in Calculation and Programming, but has been shown to be driven from an electrical perspective. As is indicated in the conflicts between schools, the Electrical Engineers play a large role in ensuring effective communication, which is essentially the bridge between the School of MIA and the School of EI, which most students do not consider as part of the project per say. It is, therefore, understandable that the Electrical Engineers competency fall outside the scope of the ECSA ELO 8 requirement of Candidate Makes Individual Contribution to Team Activity, as they do not make individual contributions to the *project*, but rather to the administration of the project, such as the administration of MS Projects and documentation. Thus, their core competencies are not readily identified by other students. This is exacerbated further by the students not reflecting on their own core competencies.

Electrical Engineers are seen as specialists, and thus aspect driven, rather than systems driven. Unsatisfactory management skills and expertise further add to the lack of individual contributions, as the case studies are not necessarily electrical in nature. The identification of almost immediate clashes of opinion indicates that the electrical engineer aims to make an individual contribution, but is met with a lot of resistance due to their academic approach.

5.4.2 THE CANDIDATE ENHANCES THE WORK OF FELLOW TEAM MEMBERS

Although not outside the boundary of Analysis of Means for this particular requirement, Industrial Engineering and Mechanical Engineering will be discussed, as they are very near the confidence interval boundary, and the researcher has identified that the overlap occurs at a 92 % confidence level. Due to the small sample size of the Industrial Engineers, the researcher feels that it is important to explore these disciplines using emergent themes and extant literature.

The Industrial Engineers are identified as near the positive confidence interval for Enhances Work of Fellow Team Members. Comparing their core competencies to the ECSA ELO 8 requirements, it seems that the Industrial Engineers enhanced the work of team members by initiating a systems approach within the group as well as facilitating effective communication between group members, as identified by the emergent themes of core competencies - Project Managers Assumed Leader and Decision Maker Operations and Process Driven Business Driven and Leadership. The leadership may be construed as similar to the Electrical Engineers and Aeronautical Engineers, but it should be noted that the Industrial Engineers do not just work with the administration of the project and/or aspect leadership, but rather act as mediators between the disciplines as well as identifying the business aspects of the case study, for which no other discipline has shown as a core competency. The enhancement of the team is, therefore, identified as taking a leadership role, and acting as the project manager.

The Mechanical Engineers are identified as near the negative boundary of the confidence interval, and their emergent core competencies - Practical Approach Analysis of Each Requirement and Mechanical Aspect – assist in the understanding thereof. The Mechanical Engineers seem to perform numerous tasks, but none that are seen as crucial. It is thus understandable that reflections of students regarding Mechanical Engineering is seen as negative, as the enhancement is a combination of small functions across myriad areas of the project, and the isolation of Enhances work of team members may be overlooked by other disciplines.

5.4.3 The Candidate Communicates Effectively with Team Members

It was found that the Mechanical Engineering discipline was considered an outlier for Communicates Effectively with Team Members (92% Confidence Level) when compared to the other disciplines. The overtly positive reflection is in line with the emergent themes, as the Mechanical Engineer was found to assist almost all disciplines. It is thus reasonable to deduce that the Mechanical Engineers were required to communicate effectively with several team members.

It is also noted by the researcher that the Electrical Engineers do not have an overtly positive or negative opinion, which would be expected, given their core competencies as Detailed Assistance in Software Leadership in Calculation and Programming as project administration, along with the Information Engineers, whose core competencies were identified by emergent themes as Software-oriented, Documentation Formatting Electrical Aspect and Collaboration of Inputs. It, however, has been stated that the communication and administration of the Electrical Engineers and Information Engineers, as experienced by students, is not directly linked to the project itself, and thus most students do not consider it as a form of effective communication of the project itself.

5.4.4 The Candidate Delivers Completed Work on Time

It was found that the Aeronautical Engineering discipline was considered an outlier for Delivers Completed Work on Time (95% Confidence Level) when compared to the other disciplines. As the students were not prompted to provide a reflection on the project completion, it is considered an oddity that a particular branch would have an overtly positive reflection. Binary regression analysis has identified that the year is not a significant predictor, and thus the case studies that were used in Year 2011, which are predominantly Aeronautical in context, cannot be considered as the reason. Due to the small sample size of the Aeronautical Engineers, the researcher feels that it is important to explore these disciplines using emergent themes and extant literature.

The reflections of students in emergent themes identified the Aeronautical Engineering students as that of Explaining Technical Aspects, Design Driven and Leadership in Technical Aspects. Their core competencies are identified in both negative and positive feedback from other engineers, identifying that their technical approach is both beneficial but also frustrating, as they are especially aspect driven.

The processing of this kind of information transfer is considered as aspect engineering and not systems engineering. Using emergent themes, it may be considered that the Aeronautical Engineering students, being as specialized as they are, give concise details, and elaborate on the completion of the project, or alternatively, elaborate on the satisfaction they experienced with the project outcome.

5.4.5 Acquires a Working Discipline of a Co-Workers Discipline

It was found that the Mechanical Engineering discipline was considered an outlier for Acquires a Working Knowledge of a Co-Workers Discipline (92% Confidence Level) when compared to the other disciplines. The overtly negative reflection is in line with the emergent themes, and the findings of Enhances the Work of Fellow Team Members as well as Communicates Effectively with Team Members, as the Mechanical Engineer was found to assist almost all disciplines. It is, therefore, reasonable to deduce that the Mechanical Engineers were required to assist other disciplines with many aspects of the project, and did not reflect that they acquired a working discipline of another discipline, as they essentially act as the go-between for the other disciplines.

5.4.6 Information Engineering Discipline

The Information Engineering discipline was the only discipline that did not cross any Confidence Intervals for any of the ECSA ELO 8 requirements. The sample size of the Information Engineers is small (n=39), and the coverage of the discipline is only 8.30%. Additional data is required, as the available data is considered inadequate. Considering the emergent themes of core competency with regard to the Information Engineering Discipline - Software-oriented, Documentation Formatting Electrical Aspect and Collaboration of Inputs – it is expected that the Information students will follow a similar pattern to the Electrical Engineering Discipline.

5.5 Comparison to Pilot Study

The themes found by the pilot study were identified as Team Dynamics, Interdisciplinary Features, Time Management and Student Personal Learning, whilst the current research identified Conflicts and Difference between Disciplines and Project Management.

Although the themes were found to differ, the emergent themes were found to recur, with communication, leadership, disciplines (and differences pertaining to the disciplines), scheduling, inter-school versus in-school, and learning from other students generally consistent. A few differences were identified, such as the group formation dynamics and discourse.

Differences within the group formation dynamics are identified, in that the pilot study found that storming, norming and performing were established, whereas the current research identified that cyclical transforming was apparent, in light of the interdisciplinary requirements. While the pilot study identified attitudes, behaviours, conflict and cultural, religious and moral issues as part of team dynamics, the current research found that these differences were not emergent as themes, but rather as discourse, with very few students identifying discourse themes such as Personality Clashes, Gender Division, Language Barriers, Disciplinary Bias and Ageism. This is not to say that the themes do not exist, but that they are the exception rather than the rule, or norm.

5.6 Educational Design as a Guideline

Improvements in meeting the ECSA ELO 8 requirements per year indicate that the changes made with regard to MECN4020 have increased the inference and maximum likelihood of the requirements being met. In light of the fundamental requirements for interdisciplinary education design, each of the following requirements has been met, or alternatively, a recommendation has been given.

5.6.1 PLANNING THE APPROACH

Planning the approach requires the lecturer to ascertain the objective, to determine past experiences/entering behaviour and to identify suitable strategies.

Ascertaining the objective is seen as a requirement that is yet to be met, as outlined by the concerns with regard to the transient cross-disciplinary requirements of the ECSA ELO 8 requirements. Determining entering behaviour is considered as met, with the lecturer carefully planning the transition from individual contribution to interdisciplinary work, by the instructions given to students that the individual short-cycle and long-cycle case study analysis are not to be the same as the group project.

The identification of past behaviour is considered met, with the current research aimed at identifying suitable strategies to increase the requirements of ECSA ELO 8 being improved.

5.6.2 EXECUTION OF INSTRUCTIONAL APPROACH

The execution of instructional approach requires the identification in the role of teachers/lecturers, and the synthesis and implementation of recommendations.

Changes in the course have ensured that the role of teachers/lecturers has been fixed, with lecturers acting as both instructors and proctors. The synthesis and implementation of the recommendations are seen to have been met, with the removal of the presentation and group reflection from Year 2011, as well as the increase in self-study time (from 60 hours to 101 hours), as well as an increase in the weighting of complimentary studies (from 70% to 80%). Emphasis is placed on both the group project and individual assignments, with adaptations in the allocated marks increased by 2.5%.The change in case studies is seen as positive, as no case studies that are currently being used have been identified as having an adverse effect on meeting the ECSA ELO 8 requirements. An improvement in the meeting of ECSA ELO 8 outcomes has been noted, and as such, the reduction of project days by 11 working days is not considered adverse.

5.6.3 Evaluation of Instructional Approach

The evaluation of the instructional approach is two-fold; to evaluate the outcomes of the learners with the consideration of behaviour outcomes, and bolster the analysis with the follow up of mediation. In light of the evaluation of the instructional approach, recommendations are given in the following chapter. Consideration should be given to the consistent and continuous flow of communicating across a disciplinary boundary, so as to enforce semantic and pragmatic processing.

5.6.4 Validity and Reliability

Validity and Reliability are considered for both inductive and deductive analysis, as outlined in Chapter 3.

Inductive analysis required that the reliability of the investigation be of the standard that future research would be impervious to subject error. Entropy was calculated for each emergent theme, and the reliability of the inductive analysis upheld. A dichotomous scale ensured that the reliability was ensured. A priori approach was adopted, and inductive analysis was completed before deductive analysis. Saturation is ensured by reading all reflections of students twice, and ensuring ample coverage of coded reflections.

Deductive analysis required that internal consistency was upheld with the inclusion of node/theme qualifiers. Future research may well use the same qualifiers, if the same definitions of each requirement is used, assuming that the definition of certain terms are not changed. External validity was proven, as the results found were similar to those identified by other tertiary institutions and cross-disciplinary study. However, if changes are made to the project deliverables of MECN4020, construct effects may be a concern. Ex-ante validity is shown, with a majority of the ECSA ELO 8 requirements coded for. An improvement in the ex-ante validity is expected, as certain recommendations may ensure that a ‘codable’ reflection is increased.

Clustering and categorising of data, the examination of concepts and themes, as well as the definitions of relationships between or among concepts has been identified within this chapter, which may be seen as the rigour of data analysis.

5.7 Summary of Discussion and Exploration of Findings

This chapter started by identifying the disparities in understanding of a Systems Approach and differences between deliverables of cross-disciplinary studies in extant literature, and comparing them to the requirements of both ECSA and the MECN4020 project deliverables. The changes made to the course were compared to the predictors identified in analysis, and the differences in discipline from inductive analysis used to explain the differences in disciplines with regard to meeting the ECSA ELO 8 requirements. Comparisons were drawn with the pilot study from Year 2011, and emergent themes compared, as well as differences identified. Finally, interdisciplinary education design was used as a framework, and prior discussions aligned so that changes made to the course, as well as recommendations, could be readily identified.

6 RECOMMENDATIONS

This chapter starts off by providing a summary of the research that was undertaken. The research findings are discussed in relation to the objectives, and conclusions are drawn regarding the validity of the hypotheses. Discussion of the limitations of the research leads to a summary of the conclusions and recommendations.

6.1 Research Overview

After conducting a literature survey, a method of qualitative analysis was chosen, so that both inductive and deductive analysis could be completed. The central research question was identified as:

Does the group project for MECN4020 meet the ECSA ELO 8 requirements?

Full investigation of the problem required that the researcher identify whether the ECSA ELO requirements had been met, and to relate the findings to extant literature and emergent themes.

6.2 Hypothesis Testing

This section summarises the findings, according to the nine hypotheses generated, so that the central research question could be answered, and by the extent to which the objectives of the research have been met. The conclusions drawn may be affected by the sources of potential bias within the reflections of students, as well as the sample sizes of some predictors.

6.2.1 H_1: THE CANDIDATE DEMONSTRATES EFFECTIVE TEAM WORK

Six hypotheses have been identified as per the requirement of the ECSA ELO 8:

$H_{1\text{-Individual}}$: MAKE INDIVIDUAL CONTRIBUTIONS TO THE TEAM ACTIVITY?

The inference of the population indicates that the maximum likelihood of the student making an individual contribution falls within the confidence interval of (71.67%, 79.40%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is being met. This conclusion supports the hypothesis, and the research, therefore, states that:

The Candidate Makes an Individual Contribution to Team Activity for the group project of MECN4020.

$H_{1\text{-CRITICICALFUNCTIONS}}$: PERFORM CRITICAL FUNCTIONS?

The inference of the population indicates that the maximum likelihood of the student performing critical functions falls within the confidence interval of (38.37%, 47.28%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement cannot be considered as met. The reflections of students do not contain enough ‘codable’ context in terms of words, phrases or paragraphs. This conclusion supports the hypothesis, and the research therefore states that:

Further recommendations need to be provided before the Candidate Performs Critical Functions for the group project of MECN4020 may be considered as met.

$H_{1\text{-EMHANCE}}$: ENHANCE WORK OF FELLOW TEAM MEMBERS?

The inference of the population indicates that the maximum likelihood of the student enhancing the work of fellow team members falls within the confidence interval of (63.08%, 71.53%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is being met. This conclusion supports the hypothesis, and the research therefore states that:

The Candidate Enhances the Work of Fellow Team Members for the group project of MECN4020. Further recommendations need to be provided to increase the confidence interval.

$H_{1\text{-BENEFIT}}$: BENEFIT FROM THE SUPPORT OF TEAM MEMBERS?

The inference of the population indicates that the maximum likelihood of the student benefitting from the support of fellow team members falls within the confidence interval of (72.78%, 80.40%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is being met. This conclusion supports the hypothesis, and the research therefore states that:

The Candidate Benefits from the Support of Fellow Team Members for the group project of MECN4020.

$H_{1\text{-Communication}}$: Communicate effectively with team members?

The inference of the population indicates that the maximum likelihood of the student communicating effectively with team members falls within the confidence interval of (76.60%, 83.76%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is being met. This conclusion supports the hypothesis, and the research therefore states that:

The Candidate Communicates Effectively with Team Members for the group project of MECN4020.

$H_{1\text{-Deliver}}$ Deliver completed work on time?

The inference of the population indicates that the maximum likelihood of the student delivering completed work on time falls within the confidence interval of (25.02%, 33.19%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement cannot be considered as met. The reflections of students do not contain enough ‘codable’ context in terms of words, phrases or paragraphs. This conclusion supports the hypothesis, and the research therefore states that:

Further recommendations need to be provided before the Candidate Delivers Completed Work on Time for the group project of MECN4020 may be considered as met.

6.2.2 H_2: The Candidate Demonstrates Multidisciplinary work

Three hypotheses have been identified as per the ECSA ELO 8 requirement:

$H_{2\text{-Knowledge:}}$ ACQUIRE A WORKING KNOWLEDGE OF CO-WORKERS' DISCIPLINE?

The inference of the population indicates that the maximum likelihood of the student acquiring a working knowledge of a co-worker's discipline falls within the confidence interval of (44.23%, 53.23%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is may be considered as met. The reflections of students contain ambiguous or contradictory content. This conclusion supports the hypothesis, and the research therefore states that:

Further recommendations need to be provided to improve The Candidate Acquires a Working Knowledge of a Co-Worker's Discipline for the group project of MECN4020, although the requirement is met.

$H_{2\text{-Boundary}}$: COMMUNICATE ACROSS DISCIPLINARY BOUNDARIES?

The inference of the population indicates that the maximum likelihood of the student communicating across a disciplinary boundary falls within the confidence interval of (72.12%, 79.80%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is being met. This conclusion supports the hypothesis, and the research therefore states that:

The Candidate Communicates across a Disciplinary Boundary for the group project of MECN4020

$H_{2\text{-Approach:}}$ USE A SYSTEMS APPROACH?

The inference of the population indicates that the maximum likelihood of the student using a systems approach falls within the confidence interval of (63.52%, 71.93%) at a 95% confidence level. Based on these findings, it is concluded, on the balance of evidence, that the reflections of the students indicate that the ECSA ELO 8 requirement is may be considered as met. The reflections of students contain ambiguous or contradictory content. This conclusion supports the hypothesis, and the research therefore states that:

Further recommendations need to be provided to improve The Candidate Acquires a Working Knowledge of a Co-Worker's Discipline for the group project of MECN4020, although the requirement is met.

6.3 Study Limitations

The main limitations of the study is the assumption that assumes that any data given by students is truthful and not biased although it is being handed in for marking to a lecturer. It is assumed that all students will have the same competence in literacy in the English language as it is the language that is used for the entire degree, and no language discourse analysis regarding literacy will be done. It is assumed that the feedback from repeating students may be excluded as it is not their initial contact with systems engineering and a multidisciplinary environment, and as such, would affect the outcomes of the research. The research is limited to the field data in the form of student reflections, and any clarity required from the students is not feasible. The ELO 8 of the student for Individual working has been excluded as it is there is no method of determining the outcome from the students' personal reflections.

6.4 Summary of Conclusions

ECSA ELO 8 requirements that are considered to be met by the group project for MECN4020 are The Candidate Makes Individual Contributions, The Candidate Enhances the Work of Fellow Team Members, The Candidate Benefits from the Support of Team Members, The Candidate Communicates Effectively With Team Members, The Candidate Acquires a Working Knowledge of a Co-Workers Discipline, The Candidate Communicates Across a Disciplinary Boundary and The Candidate Uses a Systems Approach.

ECSA ELO 8 requirements that cannot be confirmed as met are The Candidate Performs Critical Functions and The Candidate Delivers Completed Work on Time

6.5 Recommendations for Improvements

The following recommendations are listed for the improvement of the MECN4020 group project, so that the ECSA ELO 8 requirements are met:

6.5.1 Ascertaining the Objective

Although the project in MECN4020 at Wits University is found to be of an interdisciplinary nature, the requirement from ECSA is to be clarified with extant literature, as the deliverables of the project of MECN4020 seem to overlap with the requirements for the ECSA ELO 9 as well.

6.5.2 Evaluation of the Instructural Approach

Consistent and continuous flow of communicating across a disciplinary boundary is to be established, beyond the short-cycle and long-cycle of the individual, so as to enforce semantic and pragmatic processing, and ensure that interdisciplinary requirements are upheld.

6.5.3 ECSA ELO 8 Requirements That Are Not Met

Leading questions are to include the instruction of a student identifying their disciplines' strong points, so that future reflections may be easily coded for the ECSA ELO 8 requirement of The Candidate Performs Critical Functions. Additional questions may be identified by the lecturer, so as to ensure the future reflections of the student include content that is 'codable' for the ECSA ELO 8 requirement of The Student Delivers Completed Work on Time. Alternatively, the mark allocated to the student for the group project may be used as a nominal scale.

6.5.4 ECSA ELO 8 Requirements That May Be Improved

Closing statements by students may be encouraged within the instruction, so that ambiguity and/or contradictory context is not given in the future reflections. Although the lecturer as requested that the students identify 'what worked' and 'what did not work', a closing statement of obstacles that were overcome may assist in the improvement of reflections that are currently Not Clear.

7 REFERENCES

Accounting Department (2013) *Multilinear Regression Analysis Definition Of Regression Accounting Essay, UK Essays*.

Agresti, A. and Coull, B. (1998) ‘Approximate is Better than "Exact for Interval Estimation of Binomial Proportions’, *The American Statistician*, 52(2), pp. 119–126.

Bahill, T. and Dean, F. (2009) *What is Systems Engineering?, Copyright © 1994 to 2009 by Terry Bahill and Frank Dean*.

Bailey-McEwan, M. (2009) *Difficulties of Mechanical engineering Students in Developing Integrated Knowledge for the Cross-Discipline of Mechatronics: A Conceptual Investigation*. University of the Witwatersrand.

Bartlett, J. E., Kotrlik, J. W. and Higgins, C. C. (2001) ‘Organizational Research : Determining Appropriate Sample Size in Survey Research’, *Information Technology, Learning and Performance Journal*, 19(1), pp. 43–50.

Benson, T. C. and Newell, W. H. (1983) ‘The Case For Interdisciplinary Studies - Response to Professor Benson’s Five Arguments’, *Issues in Intergrative Studies*, 2, pp. 1–19.

BMGI (2013) ‘Six Sigma Black Belt Training Manual’. South Africa.

Bogdan, R. Biklen, S. (2007a) *Qualitative Research For Education: An Introduction to Theory and Methods*.

Bogdan, R. Biklen, S. (2007b) *Qualitative Research For Education: An Introduction to Theory and Methods*.

Braun, D. *et al.* (2007a) ‘AC 2007-318 : INTERDISCIPLINARY TEAM TEACHING : LESSONS FOR ENGINEERING INSTRUCTORS FROM A CAPSTONE COURSE IN Interdisciplinary Team Teaching : Lessons for

Engineering'.

Braun, D. *et al.* (2007b) 'INTERDISCIPLINARY TEAM TEACHING : LESSONS FOR ENGINEERING INSTRUCTORS FROM A CAPSTONE COURSE IN Interdisciplinary Team Teaching : Lessons for Engineering', AC 2007(318), pp. 1–13.

Bryman, A. and Gibbs, G. (2008) *4 Stages of Qualitative Analysis*. 3rd editio, *Social Research Methods*. 3rd editio. Oxford: Oxford University Press.

Carlile, P. R. (2004) 'Transferring , Translating , and Transforming : An Integrative Framework for Managing Knowledge Across Boundaries', 15(5), pp. 555–568. doi: 10.1287/orsc.1040.0094.

Coombs, W. (2013) 'Research Objectives', in *Practical Research: Planning and Design*, pp. 4–7. doi: 10.4135/9781452276236.n427.

Cresswell, J. (2007) *Qualitative Inquiry & Research Design*. SAGE.

Deming, W. E. (1990) *Sample Design in business research*. John Wiley and Sons.

Denscombe, M. (2010a) *The Good Research Guide: for Small-scale Social Research Projects*.

Denscombe, M. (2010b) *The Good Research Guide: for Small-scale Social Research Projects*.

Dickerson, C. and Mavris, D. (2010) *Architecture and Principles of Systems Engineering*. CRC Press.

Dictionary.com (1999) *Material Resource Planning*, *Dictionary.com*. Available at: http://dictionary.reference.com/browse/material+requirements+planning (Accessed: 4 February 2014).

Driscoll, D. (RTI I. *et al.* (2007) *Merging Qualitative and Quantitative Data in Mixed Methods Research: How To and Why Not*, *Ecological and Environmental*

Anthropology - Wildlife Damage Management. Available at: http://digitalcommons.unl.edu/icwdmeea (Accessed: 1 January 2013).

Eda, W. (2006) '1 . Exploratory Data Analysis 1 . Exploratory Data Analysis - Detailed Table of Contents [1 .]'.

Engineering Council of South Africa (2003a) *Definition of Terms to Support the ECSA Standards and Procedures System, Document G-04, Draft 6,.*

Engineering Council of South Africa (2003b) *What is Engineering*. Available at: https://www.ecsa.co.za/engineeringsa/SitePages/What is Engineering.aspx (Accessed: 23 February 2014).

Engineering Council of South Africa (2003c) *Whole Qualification Standard for the Bachelors Degree in Engineering*.

Engineering Council of South Africa (2004) *ECSA EXIT LEVEL OUTCOMES Extract from ECSA Document*.

Fereday, J. (2006) 'Demonstrating Rigor Using Thematic Analysis : A Hybrid Approach of Inductive and Deductive Coding and Theme Development', pp. 80–92.

Fereday, J. and Muir-Cochrane, E. (2006) 'Demonstrating Rigor Using Thematic Analysis : A Hybrid Approach of Inductive and Deductive Coding and Theme Development', *International Journal of Qualitative Methods*, 5(1), pp. 80–92.

Gibbs, G. (2012) *The Quality of Qualitative Research, Reliability, Validity, Generalizability and Credibility*.

Guest, G., MacQueen, K. and Namey, E. (2012) *Applied Thematic Analysis*. SAGE Publications.

Haynes, N. (1997) 'Doing Qualitative Analysis in Psychology', in *Psychology Press*.

Health, C. *et al.* (2013) *Analysis of Case-control Studies Logistic Regression, Research Methods - II*.

Ibrahim, M. (2012a) 'THEMATIC ANALYSIS : A CRITICAL REVIEW OFITS PROCESS AND EVALUATION', *WEI International European Academic Conference Proceedings (Zagreb, Croatia)*, (2011), pp. 8–21.

Ibrahim, M. (2012b) 'THEMATIC ANALYSIS : A CRITICAL REVIEW OFITS PROCESS AND EVALUATION', *WEI International European Academic Conference Proceedings (Zagreb, Croatia)*, (2011), pp. 8–21.

Infed (2010) *Bruce W. Tuckman - Forming, storming, norming and performing in groups, Infed*. Available at: humanresources.tennessee.edu/leadership/docs/tuckman.pdf?

Jones, C. (2010) 'Interdisciplinary Approach - Advantages, Disadvantages, and the Future Benefits of Interdisciplinary Studies', *ESSAI*, 7(2009), pp. 1–6.

Karl Arunski, P.E., James Martin, Phil Brown, P.E., Buede, D. (1999) *'Systems Engineering Overview'*.

Khandkar, S. (2009) *Open coding.pdf, http://pages.cpsc.ucalgary.ca/~saul/wiki/uploads/CPSC681/open-coding.pdf*.

King, A. (2014) *In Vivo Coding, The SAGE Encyclopedia of Qualitative Research Methods*. doi: 10.2203/dose-response.14-012.Vijayalaxmi.

Klein, J. T. (2008) 'Evaluation of interdisciplinary and transdisciplinary research: a literature review.', *American Journal of Of Preventive Medicine*, 35(2), pp. S116-23. doi: 10.1016/j.amepre.2008.05.010.

Lofland, J. *et al.* (2006) 'Analyzing Social Settings', in *A guide to Qualitative Observation and Analysis.* Belmont, CA: Wadsworth/Thomson.

Ludwig, S. (2002) *Introduction to the System, The Systems Approach*.

Manion, L., Morrison, K., C. (2011) *Research Methods in Education*.

Mansilla, B., Duraisingh, D. and Question, G. (2009) ‘Targeted Assessment Rubric for Interdisciplinary Writing Table A2’, 80.

Marshall, M. (1996) ‘Sampling For Qualitative Research’, *Oxford University Press*, 13(6), pp. 1–4.

Maura Borrego, L. K. N. (2010a) ‘Definitions of Interdisciplinary Research: Toward Graduate-Level Interdisciplinary Learning Outcomes’, *Review of Higher Education*, 34(1), pp. 61–84.

Maura Borrego, L. K. N. (2010b) ‘Definitions of Interdisciplinary Research: Toward Graduate-Level Interdisciplinary Learning Outcomes’, *Review of Higher Education*, 34(1), pp. 61–84.

McLoed, S. (Simply P. (2007) *Qualitative vs. Quantitative*, *Simply Psychology*. Available at: https://www.simplypsychology.org/qualitative-quantitative.html.

Miller, M. (2003) *Reliability and Validity*. Western International University.

News24, S. A. (no date) *Racism In Science Research Rising*, *News 24*. Available at: http://www.news24.com/Technology/News/Racism-in-science-research-rising-20140215.

Nicholson, C. (1987) *Postmodernistm and the Present State of Integrative Studies: A Reply to Benson and His Critics*, *Issues in Integrative Studies*. Rider College.

NVivo (2013a) *About Coding*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_coding.htm, (Accessed: 23 February 2014).

NVivo (2013b) *About Nodes*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_relationships.htm (Accessed:

23 March 2014).

NVivo (2013c) *About Sources, NVivo 10*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_sources.htm (Accessed: 23 February 2014).

NVivo (2013d) *Classification of Nodes*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_classifications.htm (Accessed: 23 February 2014).

NVivo (2013e) *Cluster Analysis*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_cluster_analysis.htm?rhsearch=cluster analysis (Accessed: 23 February 2014).

NVivo (2013f) *Help - Relationship Classification*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_classifications.htm (Accessed: 23 February 2014).

NVivo (2013g) *Help - Source Classification*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_classifications.htm (Accessed: 23 February 2014).

NVivo (2013h) *Run a Matrix Coding Query, NVivo 10*. Available at: http://help-nv10.qsrinternational.com/desktop/procedures/run_a_matrix_coding_query.htm?rhsearch=matrix coding (Accessed: 23 February 2014).

NVivo (2013i) *Run a Word Frequency Query, NVivo 10*. Available at: http://help-nv10.qsrinternational.com/desktop/procedures/run_a_word_frequency_query.htm?rhsearch=word frequency (Accessed: 23 February 2014).

NVivo (2014) *Node Classification*. Available at: http://help-nv10.qsrinternational.com/desktop/concepts/about_classifications.htm (Accessed: 23 February 2014).

Palmer, B. (2006) 'Professors Preach 10 Commandments of Team Teaching', *The*

Stanford Report, Vol. XXXVI(No.20).

Peck, M. S. (1987) *The Different Drum: Community Making and Peace*. Simon & Schuster.

Ramo, Simon, St.Clair, R. (1998) *The Systems Approach*. First Edit. TRW INC.

Ramo, S. and St Clair, R. (1998) *The Systems Approach - Fresh Solutions to Complex Problems Through Combining Sciene and Practical Common Sense*. First. California: KNI Incorporated.

Sandhya, N., Lalitha, S., Govardhan, A., Anuradha, K. (2014) *Analysis of Similarity Measures for Text Clustering*. Hyderabad.

Siddiqui, M. (2013) '" System Approach In Teaching "', *Indian Journal of Applied Research*, 3(2), pp. 84–86.

Simonoff, J. (2012) *Logistic Regression - Modeling the Probability of Success*.

Smith, M. K. (2005) 'Bruce W. Tuckman - forming, storming, norming and performing in groups', *The Encyclopaedia of Informal Education*.

Statistical Services Centre (2001) 'Approaches to the Analysis of Survey Data', pp. 1–28.

Strauss, A. (1987) *Qualitative Analysis for Social Scientists*. Cambridge.: Cambridge University Press.

Sunjka, B. (2011a) 'Project MECN 4020_2011'.

Sunjka, B. (2011b) *Teaching Systems Engineering Principles at an Undergraduate Level : Reflections of Students*.

Sunjka, B. (2011c) *Undergraduate Level : Reflections of Students*. Johannesburg.

Sunjka, B. (2012a) 'MECN 7058 Investigational Projects', p. 20.

Sunjka, B. (2012b) *Project MECN 4020_2012*.

Sunjka, B. (2013) 'MECN 4020_SE Assignment_2013'.

Tanis, H. (2006) *Probability and Statistical Inference*. Seventh Ed. Pearson.

The University of Missouri (2014) *Qualitative Research Designs*, *University of Missouri - St. Louis*.

The University of South Alabama (2014) *Chapter 12 - Qualitative Research*, *Lecture 12*.

University of the West of England (2013) *Non-probability sampling : quota sampling*, *http://ro.uwe.ac.uk/RenderPages/RenderLearningObject.aspx?Context=6&Area=1&Room=3&Constellation=28&LearningObject=163*.

University of the Witwatersrand (2009) *Aeronautical Engineering*. Available at: http://www.wits.ac.za/academic/ebe/mecheng/departments/22685/aeronautical_engineering.html (Accessed: 23 February 2014).

University of the Witwatersrand (2012) *A Career in Electrical & Information Engineering*. Available at: http://www.eie.wits.ac.za/sites/default/files/u3/booklet.pdf, (Accessed: 23 February 2014).

University of the Witwatersrand (2013a) *Industrial Engineering*. Available at: http://www.wits.ac.za/academic/ebe/mecheng/departments/22683/industrial_engineering.html (Accessed: 23 February 2014).

University of the Witwatersrand (2013b) *Mechanical Engineering*. Available at: http://www.wits.ac.za/academic/ebe/mecheng/departments/22684/mechanical_engineering.html.

Utah State University (2014) *Distance Education Proctors*, *Materials & Testing*

Service.

White, A. A. K. (2009) *'From Comfort Zone to Performance Management'*.

Wolfe, C. R. (2003) *Interdisciplinary Writing Assessment Profiles, Issues in Integrative Studies*.

Wray, R. B., Snoderly, J. and Olson, R. (1994) 'A Process Description for a New Paradigm in Systems Engineering', (August).

Wren, J. and Phelan, C. (2005) *Exploring Reliability in Academic Assessment, UNI Office of Academic Assessment*.

Yeasmin, S. and Rahman, K. (2012) '"Triangulation" research method as the tool of social science research', *Bup Journal*, 1(1), pp. 154–163. Available at: http://bit.ly/25jPswl.

APPENDIX

Appendix A – Difference in Case Studies

Table A-1: Case Studies for 2011, 2012, 2013

Year	2011	2012	2013
Case Studies Assigned	• Global Positioning System • Hubble Telescope • Theatre Battle Management System • F-111 Fighter • C-5 Cargo Airlifter • International Space Station • A-10 Attack Aircraft • KC-135 Simulator • Global Hawk B-2 Stealth bomber • MH-53J/M helicopter • T6A Texan II	• GOES-N • Genesis	• The Toronto Sun and Caribana • World Outreach Expansion Project

Appendix B – Outline of Course by Year

<u>Outline of Fourth Year Systems Engineering and Management</u>

The University of the Witwatersrand has introduced a fourth year course into their Engineering schools, which teaches Systems Engineering Principles at an Undergraduate Level . It is used to introduce the basic principles of systems engineering, so that students may become familiar with practices and methodologies such as (Sunjka 2011) (Sunjka 2012) (Sunjka, 2013):

- Project Management principles: Project management methodologies, the matrix organisation, project organisation and project functions, network scheduling: PERT and CPM, resource allocation, and contracts management
- Production and Operations Management**:** Introduction to manufacturing concepts and factors of production. Inventory control concepts; production management overview – MRP, MRP II, master scheduling and scheduling, 'JIT' concepts; overview of quality management, maintenance and reliability, supply chains.
- Management issues concerning social issues
- General Management principles
- Systems thinking principles in the context of production and operations in different industries, including the interaction between "hard" and "soft" systems.
- Work in inter-disciplinary groups
- Safety and the Environment.

The students are given a project, whereby a group of 5 students from different engineering schools are required to execute a case study analysis. The project requires that the students conduct reading and research on the case study, mapping (through drawings, graphics, diagrams) and explanation of the systems and explain the Systems Engineering process, methodology and life-cycle for the product. Students are also asked to provide a background to the product developed in the project (Sunjka 2011) (Sunjka 2012) (Sunjka, 2013).

Of pivotal importance, students are required to explain what aspects of the project presented problems, particularly from a Systems Engineering perspective, and why. Finally, the students were asked to evaluate, from the perspective of their group, whether the project was successful and why, and what the key learning principles were (Sunjka 2011) (Sunjka 2012) (Sunjka, 2013).

The outcome for the course is based on internal outcomes decided by the School of Engineering, with both the composition of mark allocation, assessment criteria and due performance requirements outlined. The ECSA Assessment at Exit Level requires that students show individual, team and multidisciplinary working, with the desired outcome that of competence to work effectively as an individual, in teams and in multidisciplinary environments. (Engineering Council of South Africa, 2003c)

Includes that hand-outs given by Wits University for the project deliverables for subject MECN4020, as follows:

Year 2011:

University of the Witwatersrand, Johannesburg

School of Mechanical, Industrial and Aeronautical Engineering

MECN4020 Systems Management and Integration

<u>Project 2011 (Inter-disciplinary Group)</u>

<u>Handed out:</u> Monday, 21 February 2011

<u>Due Date</u>:

<u>Project Presentations</u>: 30 May, 2 June, 6 June and 9 June

<u>Project Written Document Due Date</u>: Monday, 6 June 2011as per School submission policy

---

The project counts 50% towards the final course mark as per the Course Outline.

Please note that 10% of the mark will be based on communications aspects of the answers, for example, clarity of explanations, appropriate use of language etc.

<u>PROJECT BRIEF</u>

<u>Inter-disciplinary Group Formation</u>

Form a group of 5 students from the class of the following composition:

1 Electrical Eng student

1 Aeronautical Eng student

1 Industrial Eng student

1 Information Systems Eng student

1 Mechanical Engineering student

NB: **there may not be more than 1 Aeronautical student per group.**

there may not be more than 1 Industrial student per group

there may not be more than 1 Information Systems student per group

when all Aeros, Industrials and Information Systems students have assigned groups then the remaining groups may be composed of Electrical and Mechanical students in a 2:3 ratio.

Email your groups (student name, student number, discipline) to me by ***5pm on Monday, 28 February 2011*** at Bernadette.sunjka@wits.ac.za (the group member from whom I receive the email will then become the group correspondent)

Case Study Choice

There are 12 Case Studies (see attached) from which your group needs to select 3 and place them in order of preference. You will be assigned one of the case studies you have selected.

Email your Case Study preference list to me by ***5pm on Monday, 28 February 2011*** at Bernadette.sunjka@wits.ac.za (in the same email as your group above)

3 Groups will be assigned per Case Study **BUT under NO circumstances should you consult with the other groups doing the same Case Study**.

You will receive your assigned Case Study by **Thursday, 3 March 2011**, via email to your corresponding group member.

Case Study Analysis

The Case Study Analysis is to be executed as a group. As a group you are required to do the following:

Further reading and research on the case study beyond the case study document in order to gain a perspective beyond that of AFIT and the authors of the case study. This additional reading and research should be reflected in your analysis, your presentation and your written report (in a literature review), and be documented in your references.

Provide a **background to the product** developed in the project i.e. requirements, design, evolution

Map (through drawings, graphics, diagrams) and explain the **Systems Engineering process, methodology and life-cycle** for the product

Explain what aspects of the project presented **problems**, particularly from a Systems Engineering perspective, and why. How were these problems **identified and resolved**?

Evaluate, from the perspective of your group, whether the project was successful and why.

What were the **key learning principles**, system engineering **and others**, from the project? Use the Friedman-Sage Matrix as a starting point.

Certain staff members will be identified for each case study as Subject Matter Experts (SMEs) and you may consult with the staff member via appointment on a limited basis. These will be provided in a document on the case study folder. *\\mech2\Work\MECN4020*

As a group and as individuals, **reflect on the experience** of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc.

Based on your reflections, each group member is to **write about 300 words on their own individual experience** of working in an inter-disciplinary group. These should be included in the appendices of your written report. You will receive **an individual mark** for this.

Presentations

As a group, you are required to compile a Power-point presentation that will take an audience of your peers and staff members through your Case Study Analysis.

This should be presented as a group.

The presentation should last 12 mins plus 3 mins for questions.

1 slide should include a summary of your experience of working in an inter-disciplinary group.

The power-point presentation should be included as an appendix in your written report.

You will receive a mark for the presentation as determined by your peers and staff members. This mark will contribute **50% to your final project mark**.

Report

As a group, you are required to compile a written Report on your Case Study Analysis.

This should be compiled as a group.

The body of the report should be no more than 10 typed pages (Times Roman font, 11pt, 1.5spacing), excluding contents, symbol/table/diagram lists, reference list, appendices.

The report should adhere to the good report writing principles you have been taught throughout your degree.

This should NOT be a mere rehashing of the Case Study report!!

The power-point presentation should be included as an appendix in your written report.

You will receive a mark for the report. This mark will contribute **50% to your final project mark** (40% for the report and 10% for the individual reflection).

Indicate the percentage contribution of each group member to the overall group effort i.e. the analysis, presentation and report together. This should be in the form of a signed (by all group members) declaration.

Instructions for submission:

Hand-in the Project Report the School of Mechanical, Industrial and Aeronautical Engineering as per school submission policy.

Late submissions will be penalized. 5% will be deducted for the first day late (i.e. submission at anytime of 7 June). Thereafter, a further 2% per day will be deducted.

Case Studies available for selection:

All case studies are available on the AF CSE website www.afit.edu/cse/cases.cfm or on the 4th year folders at *\\mech2\Work\MECN4020*

CASE STUDY	S.M.E.
Global Positioning System (GPS) (space system)**	TBD
Hubble Telescope (space system)	Mr. R. Paton (NWE F20)
Theater Battle Management Core System (TBMCS) (complex software development)	TBD
F-111 Fighter (joint program with significant involvement by the Office of the Secretary of Defense [OSD])	Dr. C. Law (SWE 105)
C-5 Cargo Airlifter (very large, complex aircraft)	Dr. R. Reid (NWE C9)
International Space Station (highly complex multinational manned space system)	Mr. R. Paton (NWE F20)
A-10 Attack Aircraft (competitive development of critical technologies) **	
KC-135 Simulator (complex hardware in the loop simulation)**	Dr. R. Reid (NWE C9)

Global Hawk (development of critical technologies)**	TBD
B-2 Spirit stealth bomber (complex aircraft development)*	Mr. M. Boer (SWE 10D)
MH-53J/M PAVE LOW III/IV helicopter (integration of complex systems)**	Dr. C. Law (SWE 105)
T-6A Texan II (competitive aircrew training system)**	TBD
	Mr. M. Boer (SWE 10D)

***** Google this one

**Only these case studies have accompanying Executive Summaries

Year 2012:

University of the Witwatersrand, Johannesburg

School of Mechanical, Industrial and Aeronautical Engineering

MECN4020 Systems Management and Integration

<u>Project 2013 (Individual and Multi-disciplinary Group)</u>

<u>Handed out:</u> Monday, 11 February 2012

<u>Hand in 1:</u> Tuesday, 19 March 2012 (individual)

<u>Hand in 2:</u> Friday, 10 May 2012 (group)

The ***project counts 50% towards the final course mark*** *as per the Course Outline.*

Please note that 10% of the mark will be based on communications aspects of the answers, for example, clarity of explanations, appropriate use of language etc.

PROJECT BRIEF

Multi-disciplinary Group Formation

Form a group of 5 students from the class of the following composition:

1 Electrical Eng student

1 Aeronautical Eng student

1 Industrial Eng student

1 Information Eng student

1 Mechanical Engineering student

NB: there may not be more than 1 Aeronautical student per group.

there may not be more than 1 Industrial student per group

there may not be more than 1 Information Systems student per group

when all Aeros, Industrials and Information Systems students have assigned groups then the remaining groups may be composed of Electrical and Mechanical students in a 2:3 ratio.

Case Study Choice

There are 2 Case Studies (see at end of this brief) from which your group needs to select 1.

Capture your Case Study preference and groups on the spreadsheet on the course website https://sites.google.com/site/witssystemsmanagement/

by ***5pm on Monday, 18 February 2013***.

Case Study Analysis

You are required to follow the following process:

Individually, do the short cycle and long cycle case preparation for the case your group has chosen. This is to be completed thoroughly and handed in individually on Tuesday 19 March 2012. You will receive **an individual mark for this** (**20% of your final assignment mark**).

NOTE: Further reading and research on the case study beyond the case study document, in order to gain a perspective beyond that of the authors of the case study, is required. This additional reading and research should be reflected in your analysis, and your written report (in a literature review), and be documented in your references.

A reference list is required.

As a group, discuss the case using your individual preparation as input. As a group, you are required to come to a consensus regarding the solution to the case. You will present this in your case report.

As individuals, **reflect on the experience** of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc.

Based on your reflections, each group member is to **write about 300 words on their own individual experience** of working in an inter-disciplinary group. These should be included in the appendices of your written report. You will receive **an individual mark** for this (**10% of your final assignment mark**).

Report

As a group, you are required to compile a written Report on your Case Study Analysis.

This should be compiled as a group.

The body of the report should be no more than 10 typed pages (Times Roman font, 11pt, 1.5spacing), excluding contents, symbol/table/diagram lists, reference list, appendices.

The report should adhere to the good report writing principles you have been taught throughout your degree.

This should NOT be a mere rehashing of the Case Study report!!

You will receive a mark for the report. This mark will contribute **60% to your final assignment mark**.

Indicate the percentage contribution of each group member to the overall group effort i.e. the analysis, presentation and report together. This should be in the form of a signed (by all group members) declaration.

Instructions for submission:

Hand-in the Project Report the School of Mechanical, Industrial and Aeronautical Engineering as per school submission policy.

Late submissions will be penalized. 5% will be deducted for the first day late (i.e. submission at any time ***after 21 May 2012****). Thereafter, a further 2% per day will be deducted.*

<u>List of Case Studies</u>

These are available on the course website

CASE STUDY 1

CASE STUDY 2

Year 2013:

University of the Witwatersrand, Johannesburg

School of Mechanical, Industrial and Aeronautical Engineering

MECN4020 Systems Management and Integration

Project 2013 (Individual and Multi-disciplinary Group)

Handed out: Monday, 11 February 2013

Due Dates: 1. Case Study Assignment 1 (Individual) Wednesday, 20 March by 2pm

2. Case Study Assignments 1,2,3,4 (Group) Friday, 10 May by 2pm

3. Individual Reflection and Group Member Assessment (Individual) Friday, 10 May by 2pm

(School of Mechanical, Industrial and Aeronautical Engineering – South West Engineering Building – in submission boxes outside SWE 110)

- The Project counts 50% towards the final course mark as per the Course Outline.
- Please note that 10% of the mark will be based on communications aspects of the answers, for example, clarity of explanations, appropriate use of language etc.

PROJECT BRIEF

1. Multi-disciplinary Group Formation

• Form a group of 5 students from the class of the following composition:

o 1 Electrical Eng student

o 1 Aeronautical Eng student

o 1 Industrial Eng student

o 1 Information Eng student

o 1 Mechanical Engineering student

NB: there may not be more than 1 Aeronautical student per group.

there may not be more than 1 Industrial student per group

there may not be more than 1 Information Systems student per group

when all Aeros, Industrials and Information Systems students have assigned groups then the remaining groups

may be composed of Electrical and Mechanical students in a 2:3 ratio.

2. Case Study Choice

• There are 2 Case Studies (see attached list) from which your group needs to select 1.

• As a group you need to agree on the Case Study you will be analyzing (individually and as a group)

• Capture your Case Study preference and groups on the Google Docs spreadsheet on the course SAKAI website by 5pm on Monday, 18 February 2013.

• You will receive confirmation of your assigned Case Study by Thursday, 21 February 2013, via the course SAKAI website.

MECN 4020 ASSIGNMENT 2013

3. Case Study Analysis

You are required to follow the following process:

A. As individuals, do the Short Cycle AND Long Cycle Analyses, and Assignment 1for the case your group has chosen.

B. As a group, you are required to do:

C. As individuals,

This is to be completed thoroughly and handed in individually by Wednesday, 20 March by 2pm . You will receive an individual mark for this (25% of your final project mark).

a. A short Cycle and Long Cycle Analysis

b. Redo Assignment 1 and complete Assignments 2,3,4

Note: discuss the case using your individual preparation as input. As a group, you are required to come to a consensus regarding the solution to the case. You will present this in your case report by Friday, 10 May at 2pm.

NOTE: I do not want to see a replication of any individuals work (from part A) as the group assignment. This will constitute a FAIL in terms of ELO 8.

a. reflect on the experience of working in an inter-disciplinary group i.e. How did working with other disciplines impact your ability to learn and understand? What were the challenges? What worked? Etc.

Based on your reflections, write about 300 words on their own individual experience of working in an inter-disciplinary group. You will receive an individual mark for this (10% of your final project mark).

b. Complete the confidential group member assessments (submit with your reflection) by Friday, 10 May at 2pm.

4. Group Report

• As a group, you are required to compile a written Report on your Case Study Analysis. This should be compiled as a group.

• The body of the report should be no more than 10 typed pages (Times Roman font, 11pt, 1.5spacing), excluding contents, symbol/table/diagram lists, reference list, appendices.

• The report should adhere to the good report writing principles you have been taught throughout your degree.

• This should NOT be a mere rehashing of the Case Study report!!

• You will receive a mark for the report. This mark will contribute 65% to your final assignment mark.

• Indicate the percentage contribution of each group member to the overall group effort i.e. the analysis, presentation and report together. This should be in the form of a signed (by all group members) declaration.

Instructions for submission:

• Hand-in the Project Report TO the School of Mechanical, Industrial and Aeronautical Engineering

• Late submissions will be penalized. 5% will be deducted for the first day late (i.e. submission at any time after 20 March 2013 and 10 May 2013). Thereafter, a further 2% per day will be deducted.

List of Case Studies

These are available on the course SAKAI website

1. CASE STUDY 1 THE TORONTO SUN AND CARIBANA

2. CASE STUDY 2 AMERICAN CONSTRUCTORS INC.: WORLD OUTREACH EXPANSION PROJECT

Appendix

Appendix C – Study of Qualitative Method and Analysis

Qualitative of research strategies and methods have the following requirements to explore as a framework (Cresswell, 2007) (Guest, MacQueen and Namey, 2012):

- Design
- Case Study
- Ethnography
- Phenomenology
- Grounded theory
- Life history
- Historical method
- Action and Applied Research
- Clinical Research.
- Thematic Concept Analysis

The research is established as ontological, which characters definition is “Reality is multiple as seen through many views. The implications of this are that the researcher reports different perspectives as themes develop in the findings. The design strategy is beyond the researchers control as the data is collected in a pre-described manner. The strategies of Life history, Historical Method, Action and Applied Research and Clinical Research are excluded from the research strategies to be scruitinised (Guest, MacQueen and Namey, 2012)(Cresswell, 2007). The following analysis will be considered:

- Narrative
- Phenomenology
- Grounded Theory
- Ethnography
- Case Study
- Thematic Content Analysis

Each approach is discussed, with the relevance to the research question and the field data compared. The Design Strategy of the research is both inductive and deductive in nature. “Naturalistic Inquiry” is considered for inductive research, as non-manipulative and non-controlling methods of analysis are required. The researcher must be open to any themes that emerge i.e. there are no predetermined constraints on the findings, as is required by a priori.

“Emergent Design Flexibility” is considered for deductive methodology, in that the approach is open to adapting the inquiry, so as to understand the situation, and avoiding rigid designs that eliminate responsiveness, and allow for new paths of discovery as they emerge (The University of South Alabama, 2014) (Cresswell, 2007). The Analysis Strategy is therefore one of Context Sensitivity, as the findings are placed in a social, historical and temporal context, with the researchers aim that of careful comparative analysis and extrapolating patterns for possible transferability and adaption in new settings (The University of South Alabama, 2014) (Cresswell, 2007).

Narrative

Narrative research begins with the experiences as expressed in lived and told stories of individuals. It is a specific type of qualitative design in which “narrative” is understood as a spoken or written text giving an account of an event/action or series of events/ actions, chronologically connected. Data is gathered from one or two individuals and reporting on the chronological ordered meaning of those experiences. Although the concept of Narrative research is strong, researchers should collaborate with participants by actively involving them in the research, as its biggest advantage is collaboration between the researcher and the researched. It requires that the researcher have keen insight into the individual’s life (Cresswell, 2007). It is thus not suited to this research.

Phenomenology

Phenomenology is the deductive qualitative approach that is taken when the researcher’s purpose is to describe experiences as they are lived, whereby each experience or reflection is considered unique and the reality of each person is their own, and therefore subjective (Fereday and Muir-Cochrane, 2006) (The University of Missouri, 2014). Phenomenological research focuses on describing what all participants have in common as they experience as a phenomenon (e.g. grief) (Cresswell, 2007).

The research question is that of understanding a particular phenomenon as well as the nature of the human being, and relies heavily on direct observation. Data is classified and ranked, and the experience examined beyond what can be communicated (The University of Missouri, 2014). The outcomes are often described from the subject's point of view (in-vivo), and themes are identified, and explanations of findings represented. Phenomenology limits the in-depth interviews to 10-15 people (Cresswell, 2007), and is therefore not suited to the scope of this research (The University of Missouri, 2014) (Bryman and Gibbs, 2008). Part of the method employed is to ask the participants two broad questions after data collection, so that a textual and structural description of the experiences, and ultimately provide an understanding of the common experiences of participants (Cresswell, 2007). This forms the essence of the method used for research as it identifies the textural and structured description. As this is not possible, the Phenomenological research method cannot be used for this data.

Grounded Theory

Grounded theory is the inductive qualitative approach that is taken when the researcher's purpose is to develop theories, so as to understand problems that exist in specific social scenes, and the response of the subjects to that particular scene (The University of Missouri, 2014). It is a constant comparative process, whereby interviews, observations and record reviews are used to formulate, test and develop propositions until a theory is developed (The University of Missouri, 2014).

Grounded Theory advocates asking specific questions such as what is going on, what are people doing, what is the person saying, what do these actions and statements take for granted, and how do structure and context serve to support maintain, impede or change these actions and statements (Klein, 2008) . The first requirement of Grounded Theory is that the researcher focuses on a process or an action that has distinct steps or phases over time. Thus, a grounded theory study has movement or some action that the researcher is attempting to explain (Cresswell, 2007). An example of a process would be he process of supporting a faculty to become good researchers.

One approach to grounded theory is that of dividing all reflections into the following (Lofland *et al.*, 2006):

1. Acts - brief events
2. Activities – of longer duration in a setting people involved
3. Meanings – what directs participants' actions?
4. What concepts they use to understand their word
5. What meaning or significance it has for them
6. Participation – peoples involvement or adaptation to a setting
7. Relationships – between people, considered simultaneously
8. Settings – the entire context of the events under study

There are various other methods of analysing field data, including the division of data into conditions, Interactions, Strategies and tactics, Consequences (Strauss, 1987), or alternatively causal adequacy, financial resources, legal/bureaucratic powers or constraints, political/interest group support, commitment and social/economic environment (Bryman and Gibbs, 2008).

An interesting approach is to observe that the following occurrences be noted within the text of field notes (Bryman and Gibbs, 2008):

1. Repetitions
2. Indigenous typologies (in vivo) – catch phrases etc jargon
3. Metaphors and analogies
4. Transitions (pauses, sections)
5. Similarities and Differences (constant comparison)
6. Linguistics connectors (because, before, after, next, closeness, examples)
7. Missing data (omission)

There are three stages from Grounded Theory (Bryman and Gibbs, 2008) (The University of South Alabama, 2014):

Open Coding

Open coding is a procedure for developing categories of information

a) Examine the text for salient categories
b) applying the codes to the text is labelling phenomena
c) The key is to avoid mere description e.g. “conferring” not “talked to manager” or “information gathering” not “reading the schedule”
d) Use constant comparative approach in an attempt to saturate. Constant comparison requires that you maintain close connection between your categories (codes) and data. By comparing data coded in the same way you, may develop a theoretical elaboration. Memos are a good way of maintaining constant comparison. Saturation is to look for the instances that represent the category and continue looking and interviewing until new information does not provide further insight into the category. This is ascertained by the idea that further sampling will not review new illuminations of the concept. This means that the category has well developed dimensions and properties, and that the relationship among categories is well established and validated (Bryman and Gibbs, 2008).

The naming of categories should be done by using theoretical ideas from literature or informant’s terms – in vivo. Categories have properties i.e. multiple perspectives of the category, and are di-mentionalised, and therefore presented on a continuum. An example using colour: The properties are Hue, tone, shade intensity (Bryman and Gibbs, 2008). The dimensions of each property could then be dark, light etc. and are called children codes. Dimensions can be developed using the “flip-flop” technique, whereby one would compare extremes on one dimension. This assists the researcher in thinking analytically rather than descriptively e.g. comparing young against old (Bryman and Gibbs, 2008). The researcher is to be vigilant of phrases like “Never” or “Always”, as this is a signal to look closer at the social process or regulation (Bryman and Gibbs, 2008).

Axial coding

Axial coding is a procedure for interconnecting the created categories, and follows the below steps (Bryman and Gibbs, 2008):

1. Causal Conditions - what influences the central phenomenon, events, incidences, happenings?
2. Central Phenomenon - The central idea, event, happening, incident about which a set of actions or interactions are directed at managing, handling or to which the set of actions is related.
3. Context -location of events.
4. Intervening Conditions - Indirect consequences or conditions.
5. Actions/Interaction strategies.
6. Consequences -Risks associated with strategies.

Each category has properties and dimensions. It is important to look for confirmations in the data, but also to find possible exceptions. Exceptions do not necessarily refute the theory, but may be used to amend or extend it (Bryman and Gibbs, 2008).

The researcher then creates a Coding Paradigm or theoretical model that visually displays the interrelationships of these axial “codings”. A theory is therefore built or generated. Selective coding – “a procedure for building a story that connects the categories producing discursive set of theoretical propositions” – will then be utilized (Bryman and Gibbs, 2008). However, one of the requirements of Grounded Theory is that the primary form of data collection, in which the researcher has the ability to return to participants with new interviews and also requires a process or action (Cresswell, 2007). Ground Theory is thus not suitable for this research.

Ethnography

Ethnography is the qualitative approach to analysis, whereby the researcher aims to describe a culture's characteristics (The University of Missouri, 2014)(Cresswell, 2007). The method employed includes the selection of a topic after reading extant literature, and formulating research questions from the literature. Inventories of sources are developed, and the researcher aims to clarify the validity and reliability of the data, including primary sources, authenticity and biases (The University of South Alabama, 2014). The analysis includes the synthesis of data and the reconciliation of conflicting evidence. Ethnography is main concerned with the discovery and description of the culture of a group of people, and is not seen as relevant to the research to be conducted for this dissertation (The University of Missouri, 2014)(Cresswell, 2007).

Case Study

Case Study Analysis is the qualitative approach to analysis, whereby the researcher uses direct observations and interactions with a subject, and analyses the experience, thereafter an in-depth description of the experience relating to a person, family, group, community or institution is formulated and formalised (The University of Missouri, 2014).

The case study approach is multidisciplinary in nature, and includes business, law, social sciences and education. This allows for multiple methods, with the data analysis approach considered a holistic description and search for themes, so that light may be shed on the case (The University of Missouri, 2014). Although this approach is considered feasible for research suggested, the methodology is seen as vary broad, and deduction is also required so as to ascertain whether the ELO 8 requirements being met by the students, rather than the discussion of themes, issues and implication only.

One of the challenges when using Case Study Strategy is that the researcher must consider whether to study one or multiple cases. The more individual case studies, the less the depth in any single case. Multiple cases are limited to five. For this particular research, the amount of variables (year, branch, case study type) would yield the results too insignificant (Cresswell, 2007).

Appendix D – Word Frequency Query and Weighting

Table D-2: Word Frequency Query

Word	Length	Count	Weighted Percentage [%]	Cumulated Weight Percentage [%]	Similar Words
Differs	7	1639	8%	16%	differ, differed, difference, differences, different, differently, differing, differs
Project	7	1520	8%	24%	project, projects
Members	7	1500	8%	31%	member, members, members', members’
Engineers	9	1354	7%	38%	engine, engineer, engineered, engineering, engineers, engineers', engineers’
Working	7	1153	6%	44%	worked, working, workings
Meetings	8	775	4%	48%	meeting, meetings
Students	8	713	4%	52%	student, students, students', students’
Problems	8	702	4%	55%	problem, problems
Disciplines	11	586	3%	58%	discipline, disciplined, disciplines, disciplines’

Experience	10	533	3%	61%	experience, experiences, experiments
Challenging	11	457	2%	63%	challenge, challenge', challenged, challenger, challengers, challenges, challenging
Individual	10	419	2%	65%	individual, individuality, individually, individuals
electricals'	12	414	2%	67%	electric, electrical, electricals, electricals'
communications	14	383	2%	69%	communal, communed, communic, communicate, communicated, communicates, communicating, communication, communication’, communications, communicators
Managing	8	379	2%	71%	manage, manageable, managed, management, management', manager, managers, managing

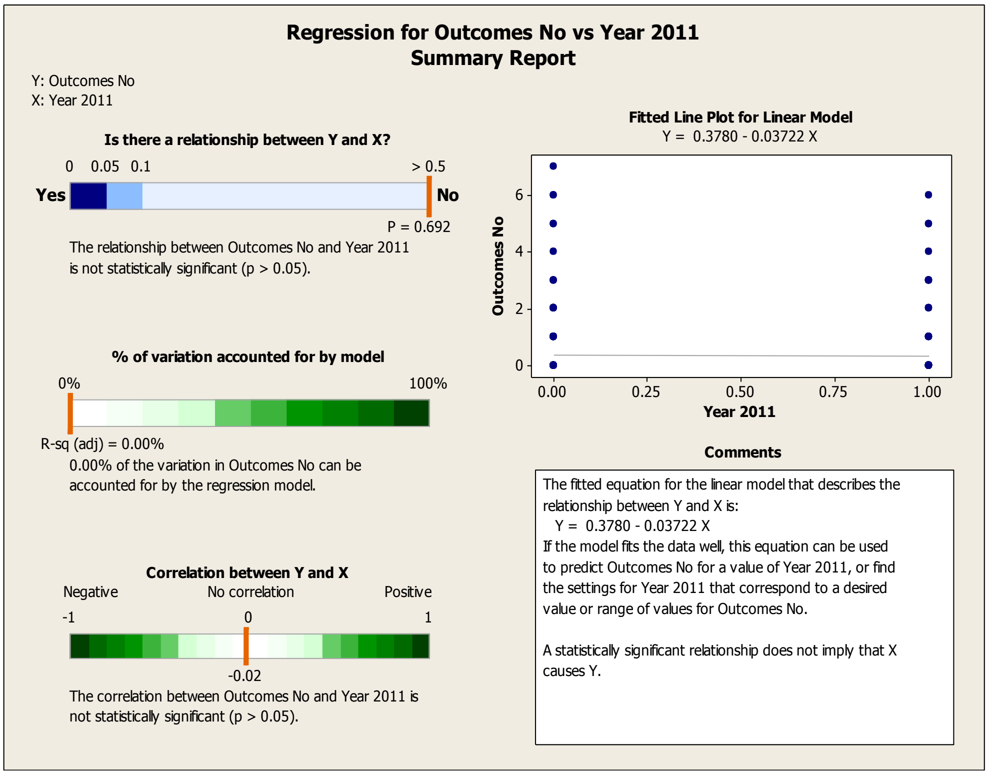
Mechanics	9	376	2%	73%	mechanic, mechanical, mechanicals, mechanicals', mechanics, mechanism, mechanisms
Approach	8	371	2%	75%	approach, approachable, approached, approaches, approaching
Assigns	7	369	2%	77%	assign, assigned, assigning, assignment, assignments, assigns

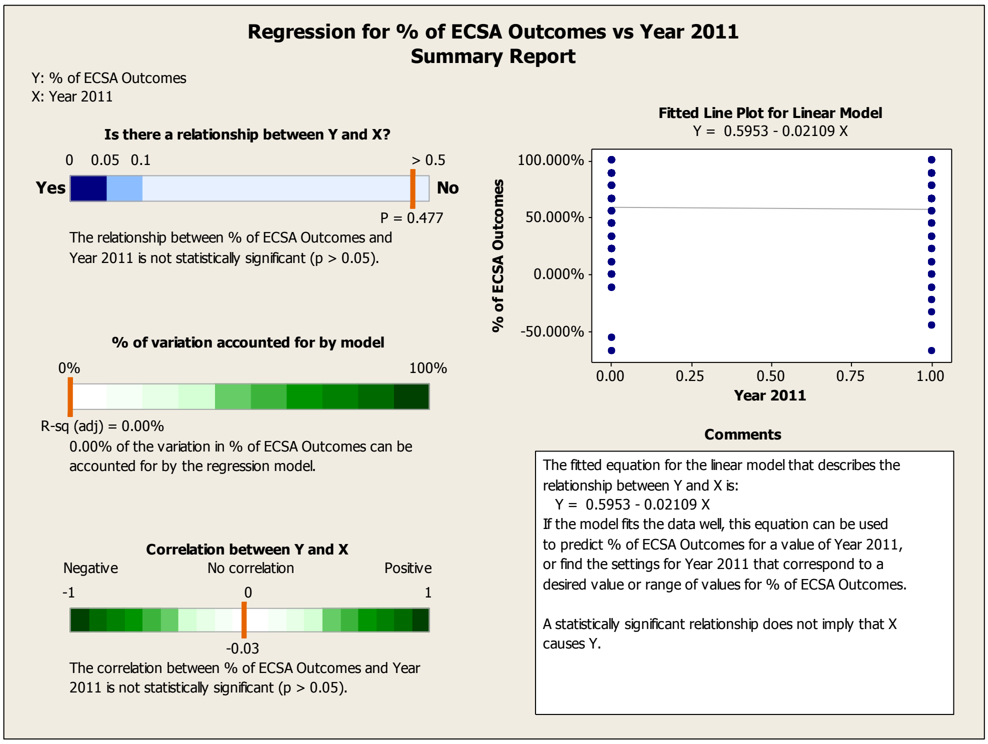
People	6	345	2%	79%	people, peoples, peoples’
understanding	13	344	2%	80%	understand, understandable, understandably, understanding, understandings, understands
Industrial	10	350	2%	82%	industrial, industrials, industry
Everyone	8	341	2%	84%	Everyone
Completion	10	339	2%	86%	complete, 'complete', completed, completely, completing, completion
Schedules	9	302	2%	87%	schedule, scheduled, schedules, scheduling
Discussions	11	282	1%	89%	discuss, discussed, discussing, discussion, discussions
Systems	7	281	1%	90%	system, 'system, systems
However	7	277	1%	92%	However
Persons	7	270	1%	93%	person, person', personal, personalities, 'personalities, personality, personally, persons
Disciplinary	12	271	1%	94%	disciplinaries, disciplinary

Informing	9	268	1%	96%	inform, informal, informally, information, informational, informative, informed,

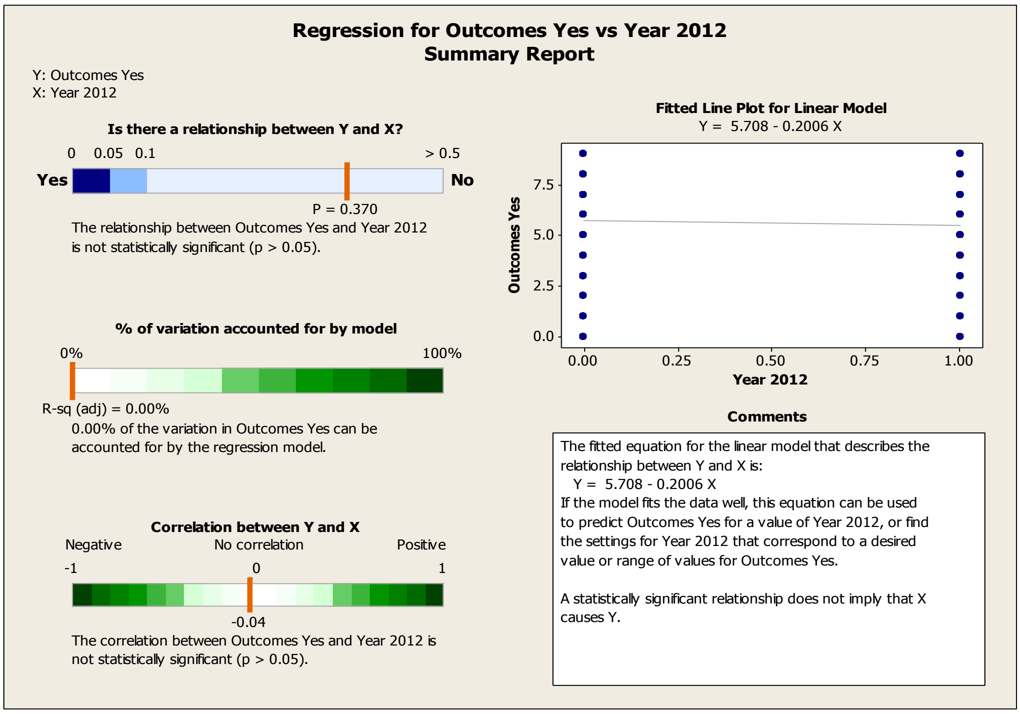
Appendix E – Regression Analysis of Categorical/Predictor data

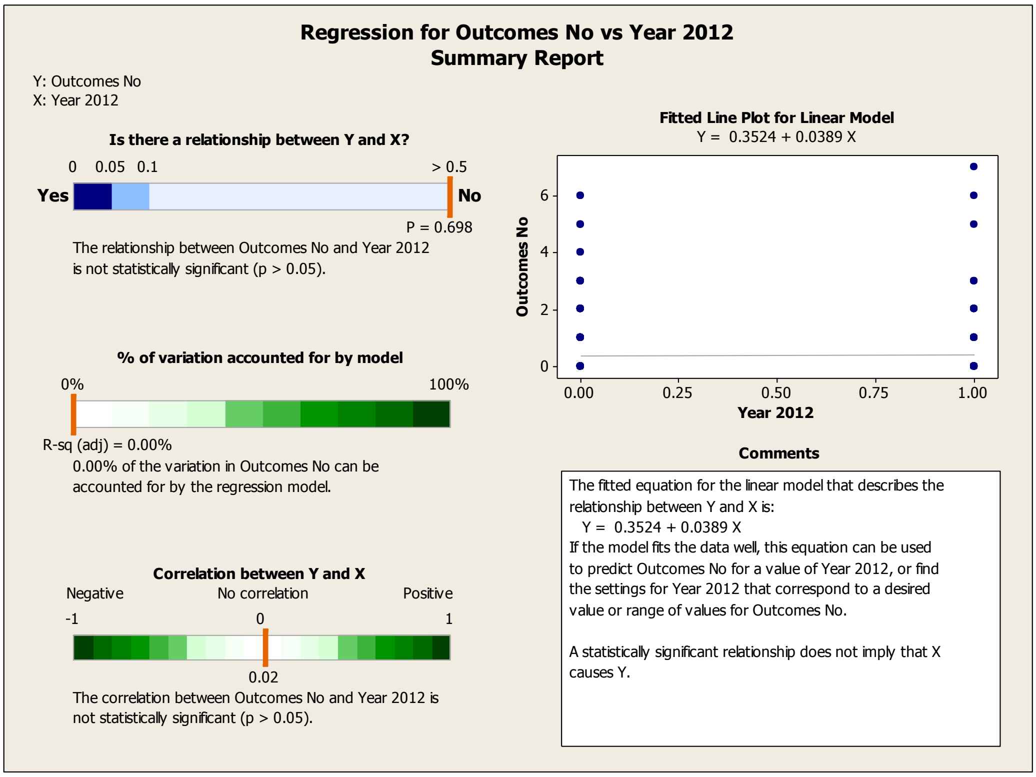
Predictor: Year 2011

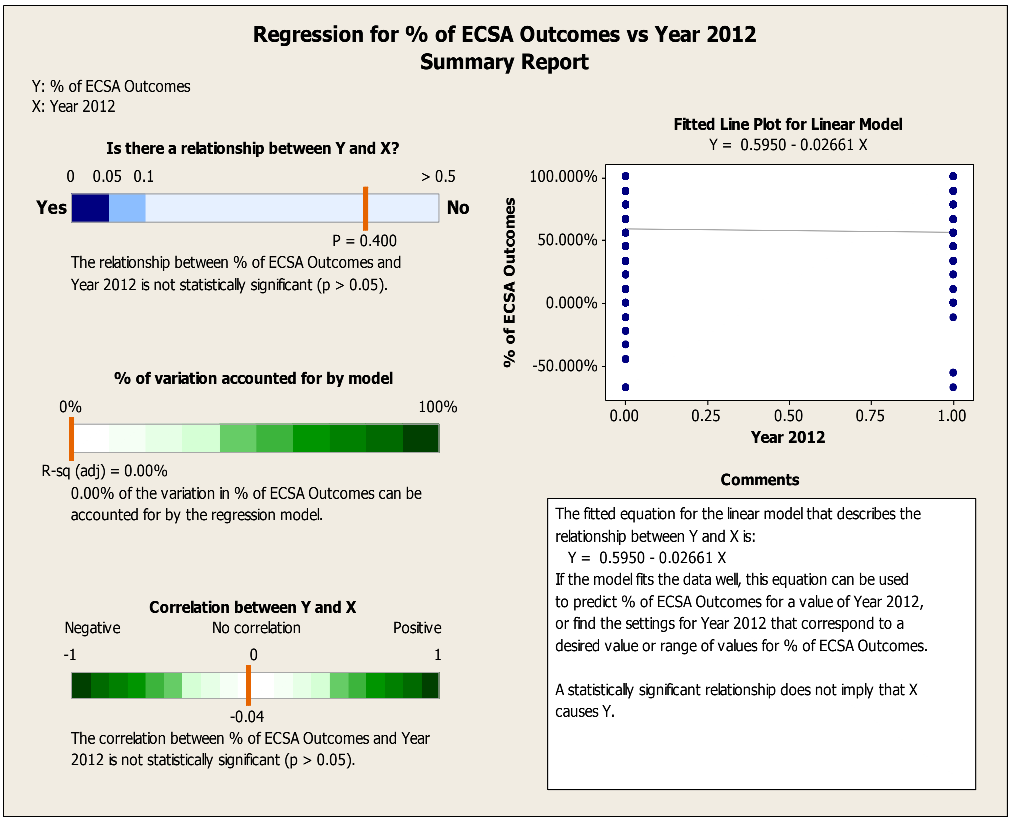




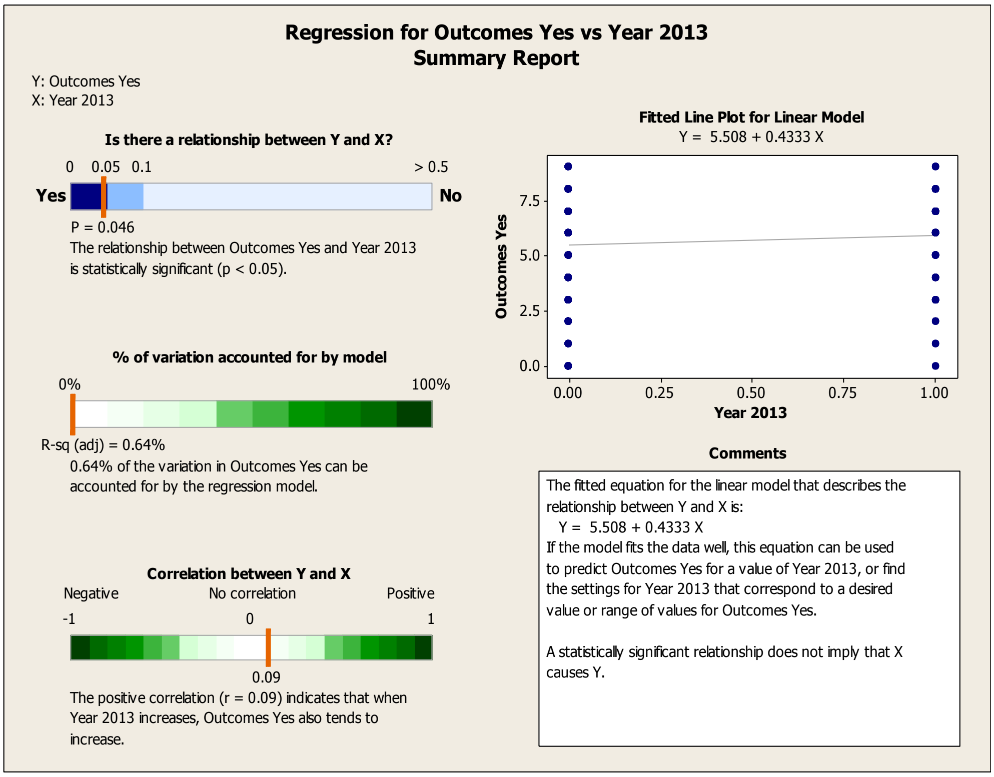
Predictor :Year 2012

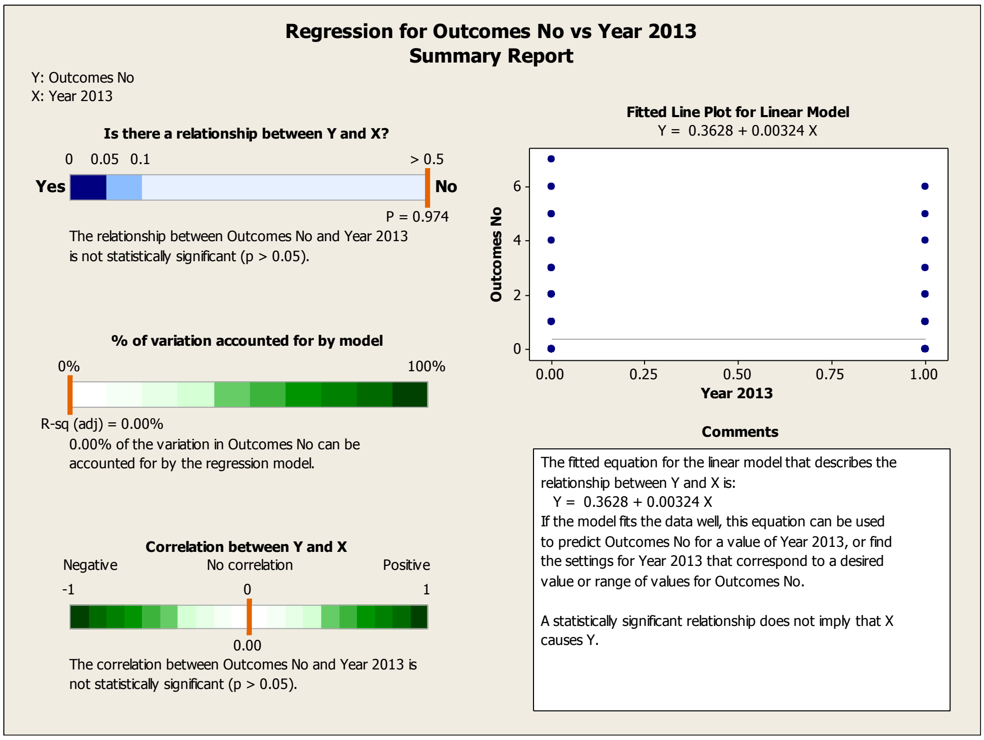


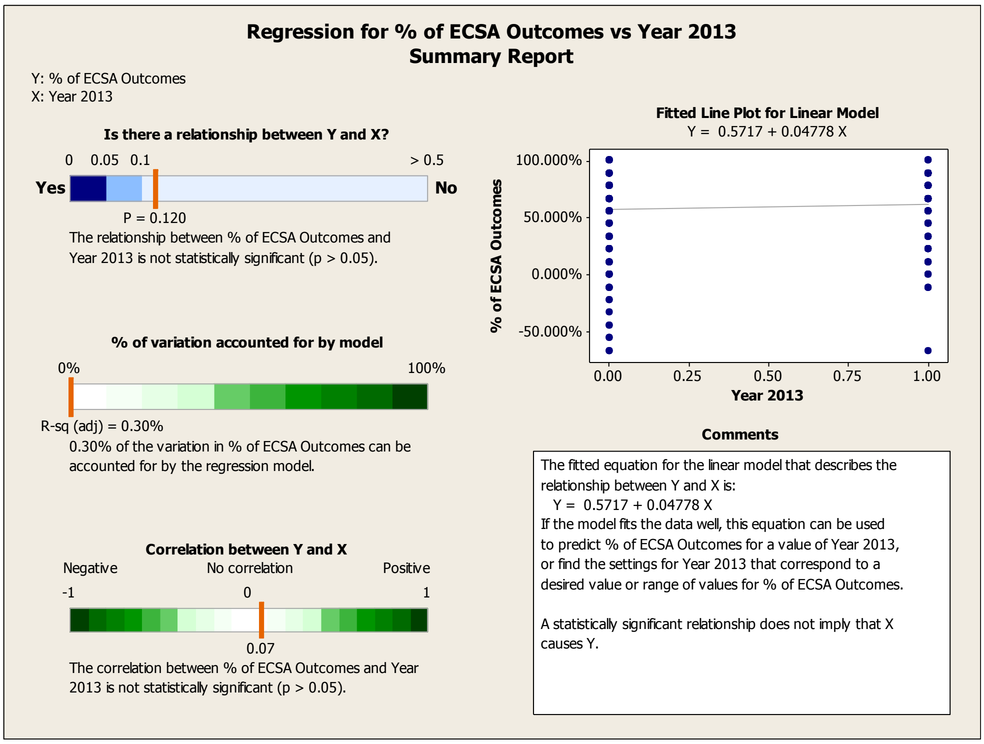




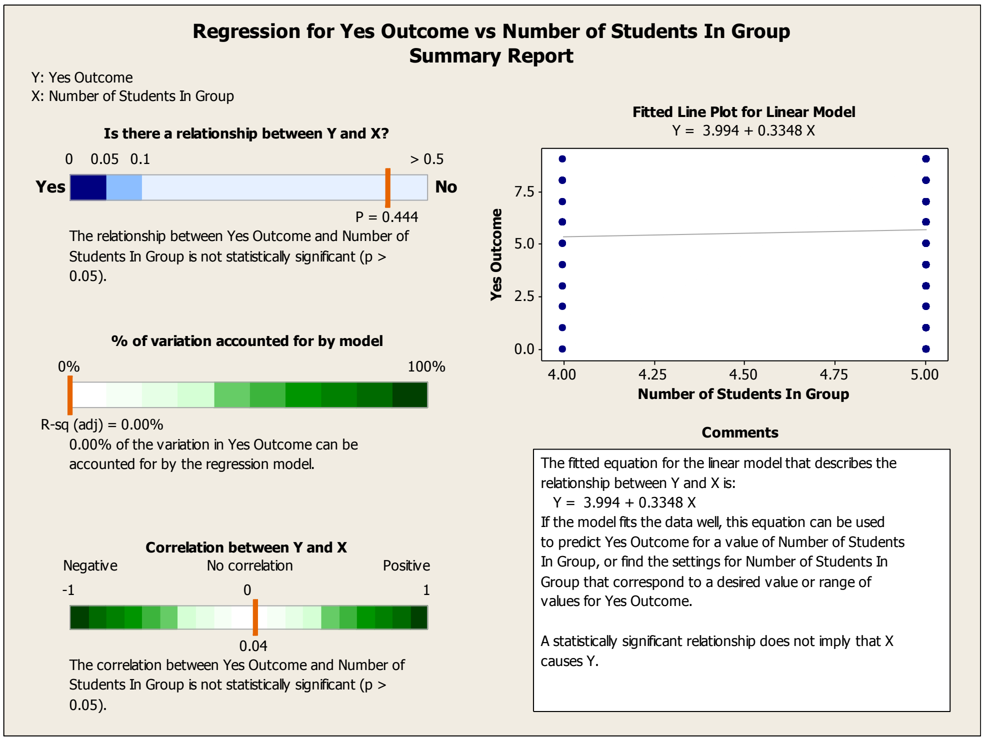
Predictor: Year 2013

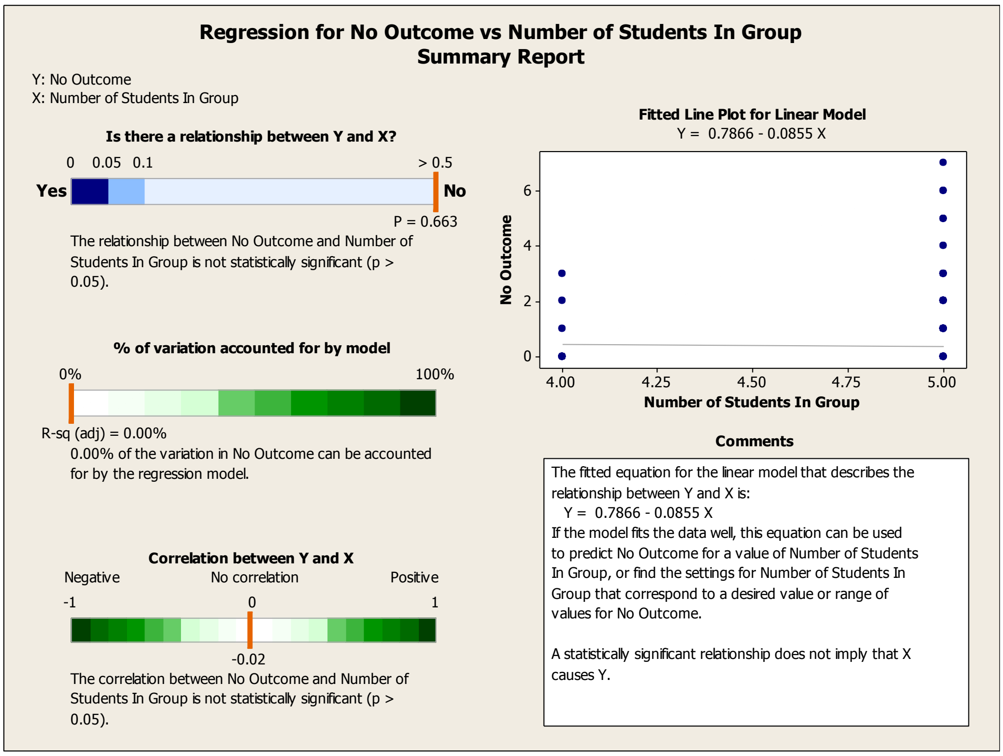


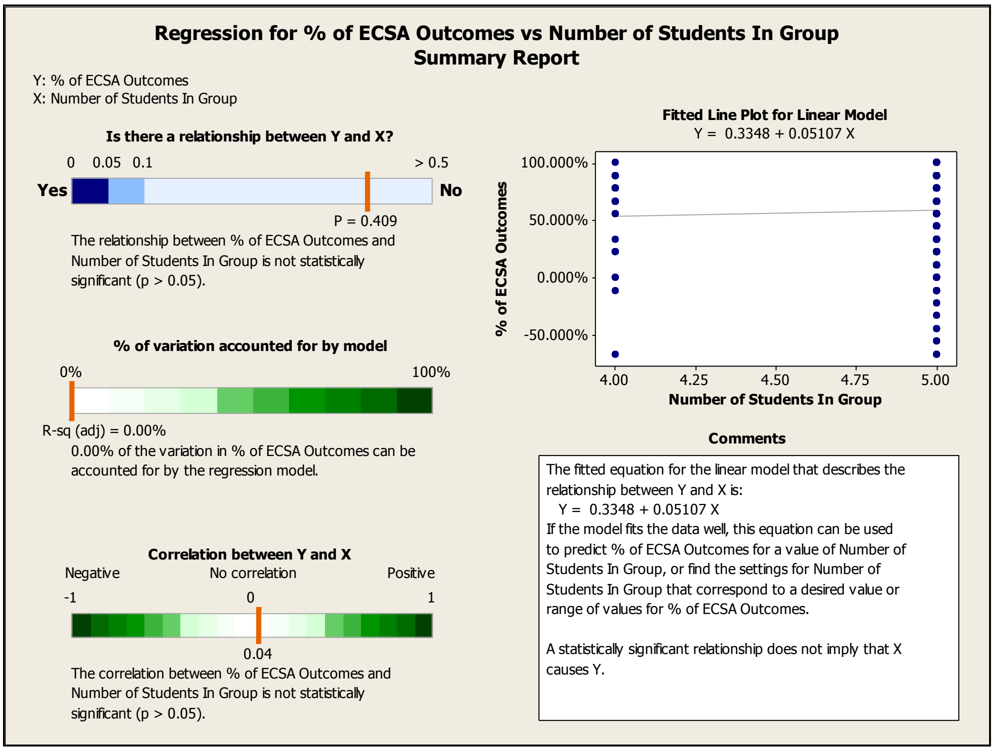

Regression for Outcomes No vs Year 2013
Summary Report
Y: Outcomes No
X: Year 2013
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes No
P = 0.974
The relationship between Outcomes No and Year 2013 is not statistically significant (p > 0.05).
% of variation accounted for by model
0% 100%
R-sq (adj) = 0.00%
0.00% of the variation in Outcomes No can be accounted for by the regression model.
Correlation between Y and X
Negative No correlation Positive
-1 0 1
0.00
The correlation between Outcomes No and Year 2013 is not statistically significant (p > 0.05).
Fitted Line Plot for Linear Model
Y = 0.3628 + 0.00324 X
Outcomes No
0 2 4 6
0.00 0.25 0.50 0.75 1.00
Year 2013
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 0.3628 + 0.00324 X
If the model fits the data well, this equation can be used to predict Outcomes No for a value of Year 2013, or find the settings for Year 2013 that correspond to a desired value or range of values for Outcomes No.
A statistically significant relationship does not imply that X causes Y.


Regression for % of ECSA Outcomes vs Year 2013
Summary Report
Y: % of ECSA Outcomes
X: Year 2013
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes No
P = 0.120
The relationship between % of ECSA Outcomes and Year 2013 is not statistically significant (p > 0.05).
% of variation accounted for by model
0% 100%
R-sq (adj) = 0.30%
0.30% of the variation in % of ECSA Outcomes can be accounted for by the regression model.
Correlation between Y and X
Negative No correlation Positive
-1 0 1
0.07
The correlation between % of ECSA Outcomes and Year 2013 is not statistically significant (p > 0.05).
Fitted Line Plot for Linear Model
Y = 0.5717 + 0.04778 X
% of ECSA Outcomes
100.000% 50.000% 0.000% -50.000%
0.00 0.25 0.50 0.75 1.00
Year 2013
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 0.5717 + 0.04778 X
If the model fits the data well, this equation can be used to predict % of ECSA Outcomes for a value of Year 2013, or find the settings for Year 2013 that correspond to a desired value or range of values for % of ECSA Outcomes.
A statistically significant relationship does not imply that X causes Y.

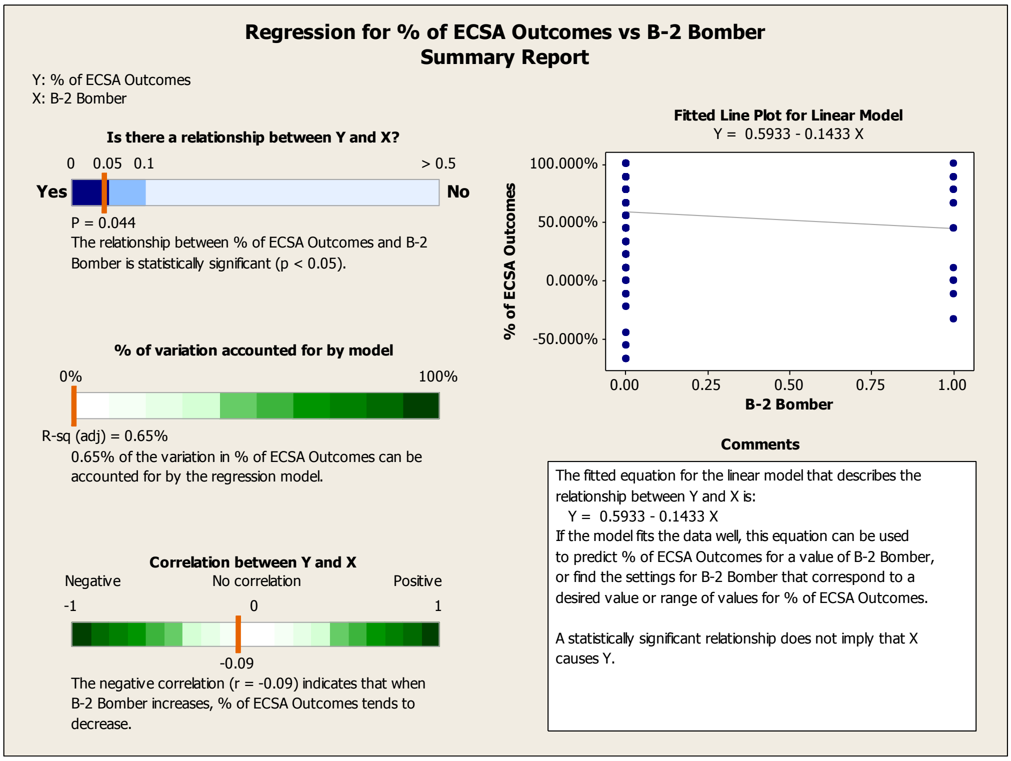
Predictor: Number of Group Members

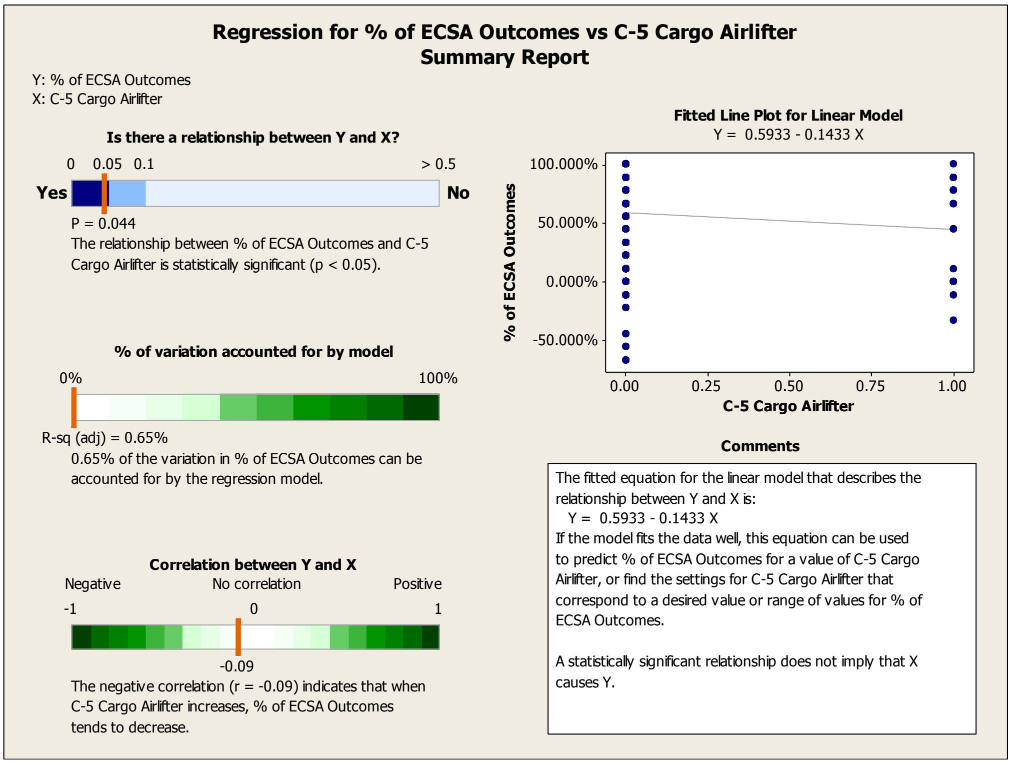


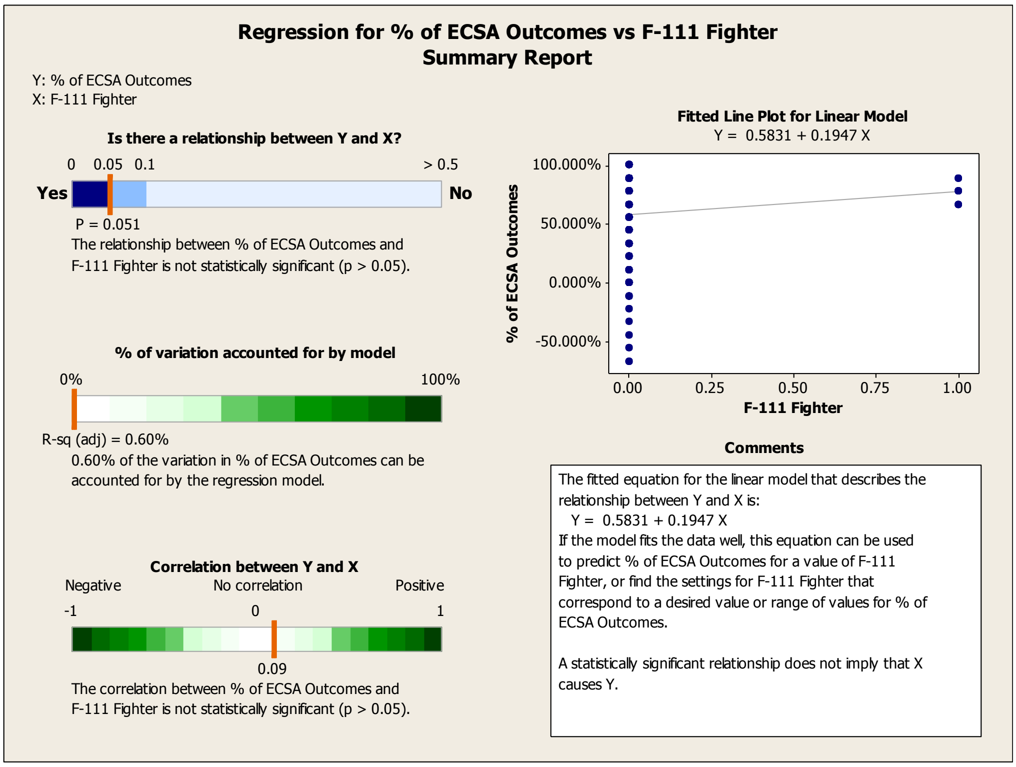


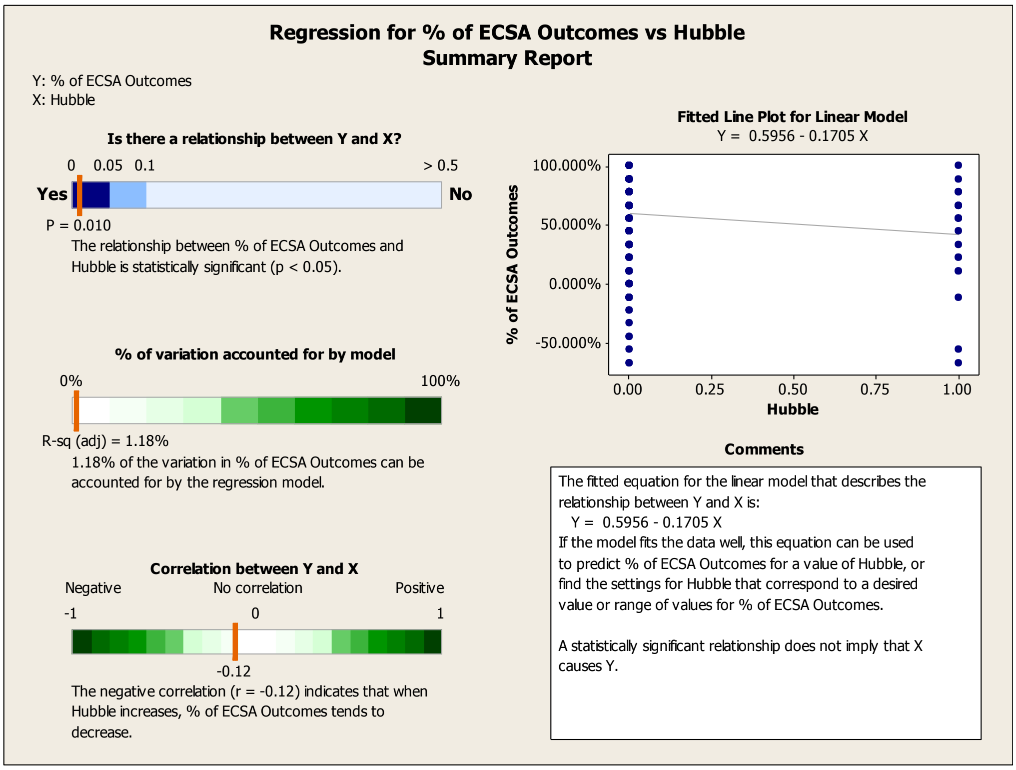

Regression for % of ECSA Outcomes vs Number of Students In Group
Summary Report
Y: % of ECSA Outcomes
X: Number of Students In Group
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes No
P = 0.409
The relationship between % of ECSA Outcomes and Number of Students In Group is not statistically significant (p > 0.05).
% of variation accounted for by model
0% 100%
R-sq (adj) = 0.00%
0.00% of the variation in % of ECSA Outcomes can be accounted for by the regression model.
Correlation between Y and X
Negative No correlation Positive
-1 0 1
0.04
The correlation between % of ECSA Outcomes and Number of Students In Group is not statistically significant (p > 0.05).
Fitted Line Plot for Linear Model
Y = 0.3348 + 0.05107 X
100.000%
50.000%
0.000%
-50.000%
% of ECSA Outcomes
4.00 4.25 4.50 4.75 5.00
Number of Students In Group
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 0.3348 + 0.05107 X
If the model fits the data well, this equation can be used to predict % of ECSA Outcomes for a value of Number of Students In Group, or find the settings for Number of Students In Group that correspond to a desired value or range of values for % of ECSA Outcomes.
A statistically significant relationship does not imply that X causes Y.

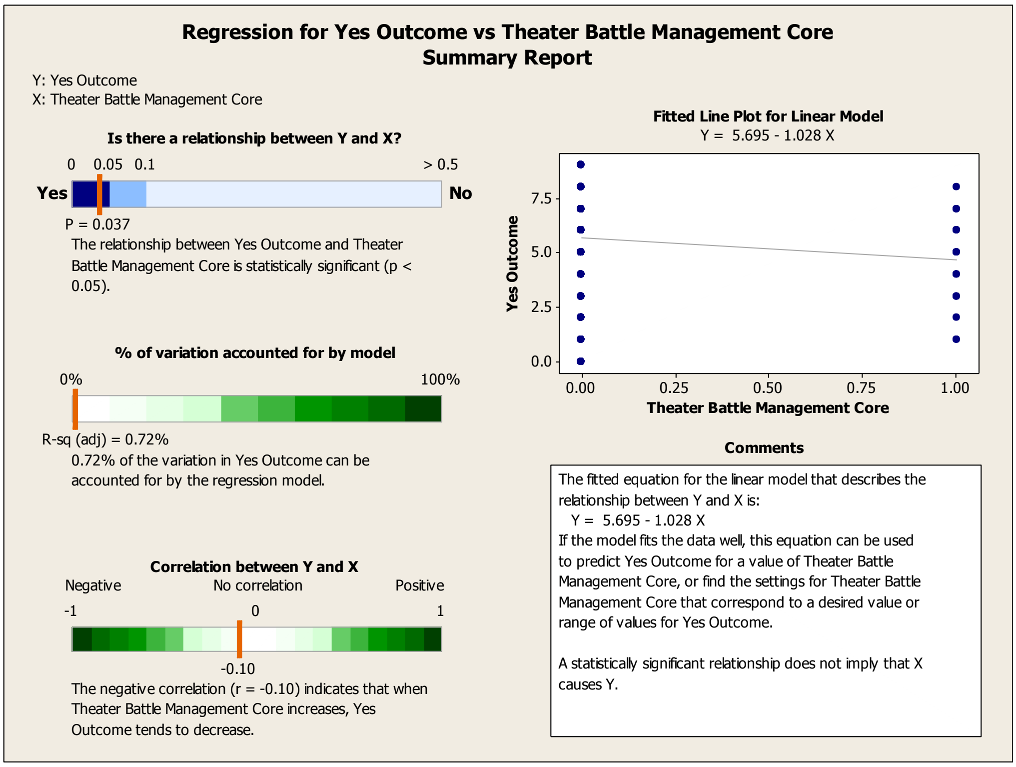
Predictor: Case Study



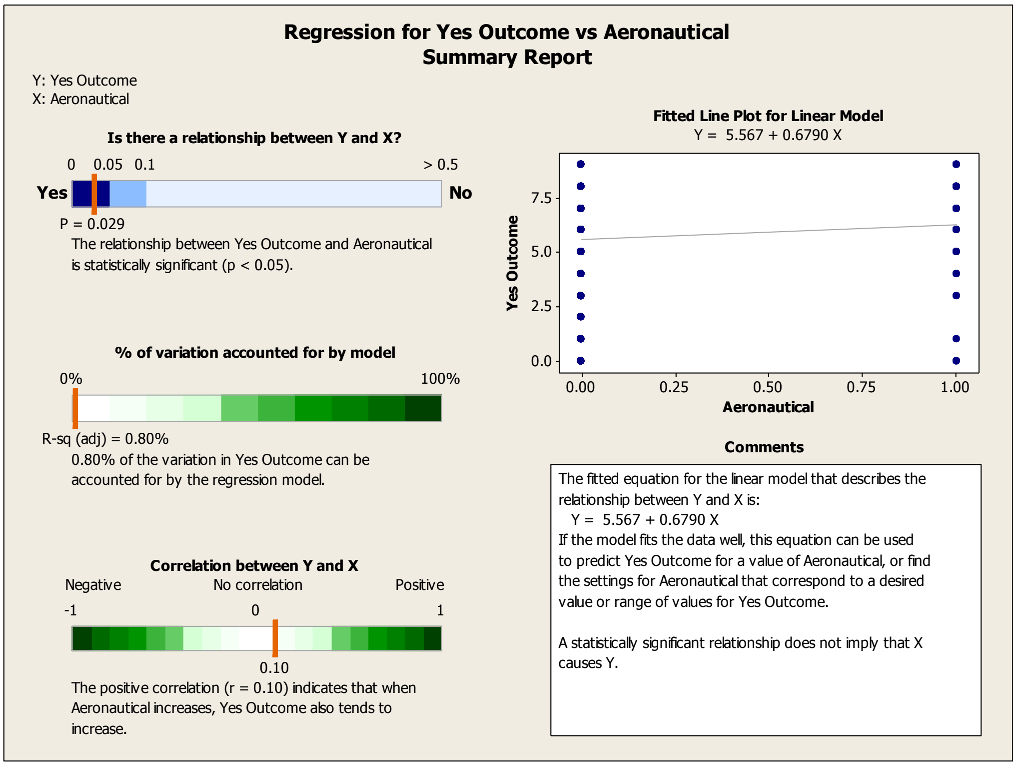


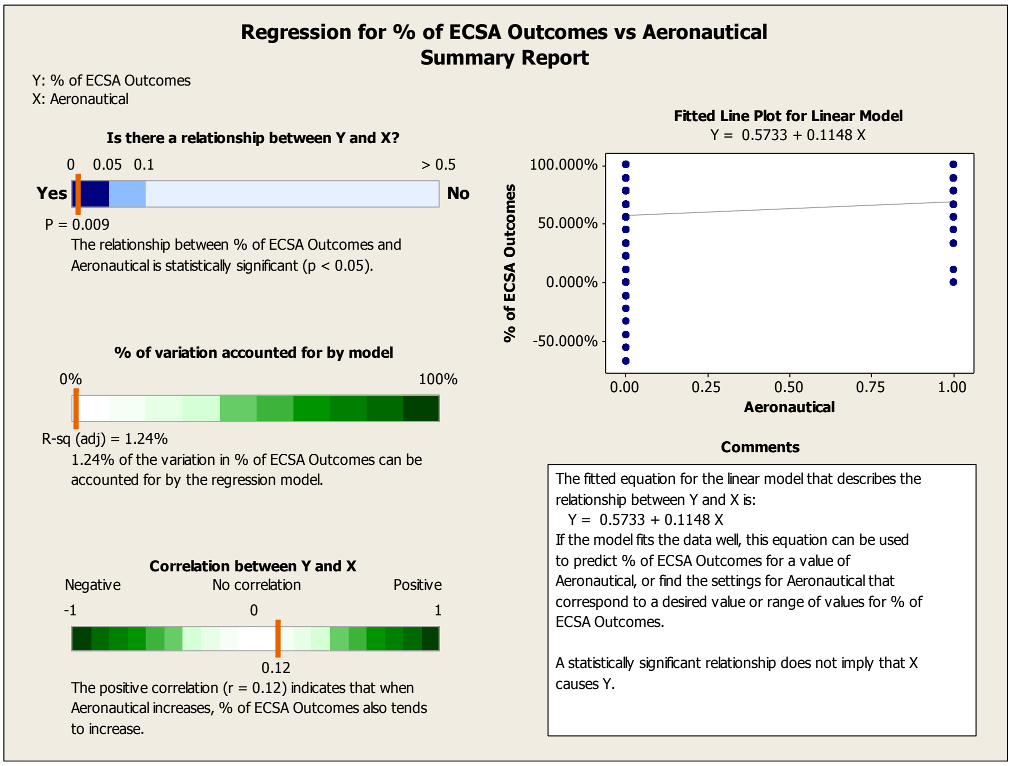

Regression for % of ECSA Outcomes vs F-111 Fighter
Summary Report
Y: % of ECSA Outcomes
X: F-111 Fighter
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes No
P = 0.051
The relationship between % of ECSA Outcomes and F-111 Fighter is not statistically significant (p > 0.05).
% of variation accounted for by model
0% 100%
R-sq (adj) = 0.60%
0.60% of the variation in % of ECSA Outcomes can be accounted for by the regression model.
Correlation between Y and X
Negative No correlation Positive
-1 0 1
0.09
The correlation between % of ECSA Outcomes and F-111 Fighter is not statistically significant (p > 0.05).
Fitted Line Plot for Linear Model
Y = 0.5831 + 0.1947 X
% of ECSA Outcomes
100.000%
50.000%
0.000%
-50.000%
0.00 0.25 0.50 0.75 1.00
F-111 Fighter
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 0.5831 + 0.1947 X
If the model fits the data well, this equation can be used to predict % of ECSA Outcomes for a value of F-111 Fighter, or find the settings for F-111 Fighter that correspond to a desired value or range of values for % of ECSA Outcomes.
A statistically significant relationship does not imply that X causes Y.

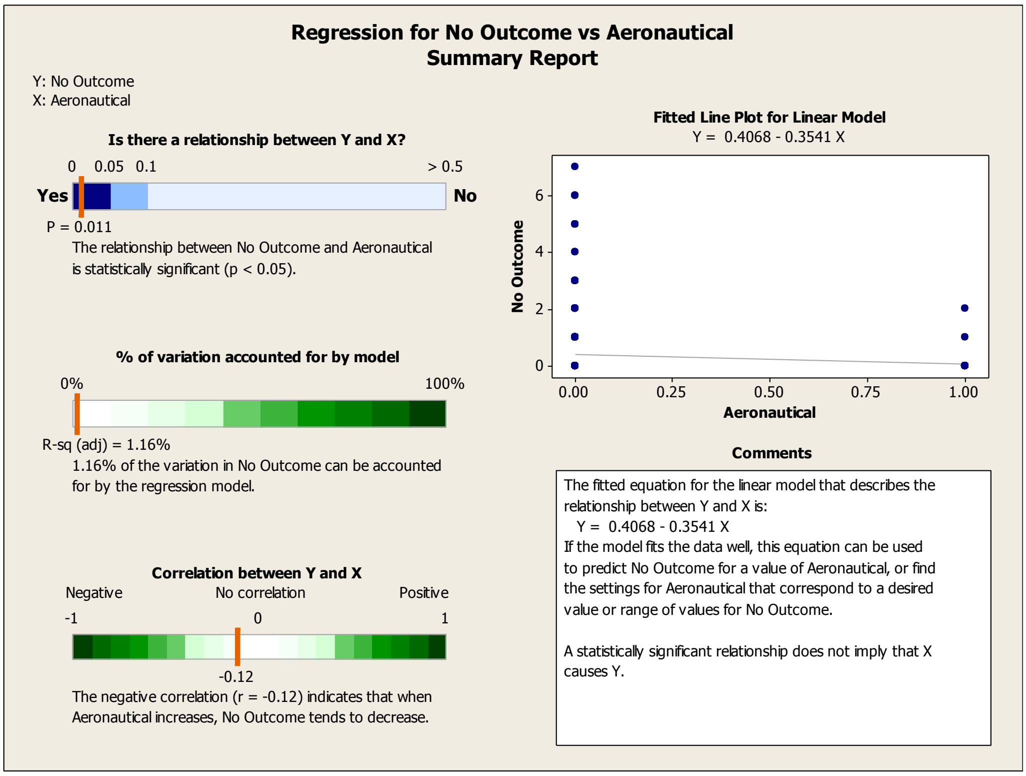

Regression for % of ECSA Outcomes vs Hubble
Summary Report
Y: % of ECSA Outcomes
X: Hubble
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes No
P = 0.010
The relationship between % of ECSA Outcomes and Hubble is statistically significant (p < 0.05).
% of variation accounted for by model
0% 100%
R-sq (adj) = 1.18%
1.18% of the variation in % of ECSA Outcomes can be accounted for by the regression model.
Correlation between Y and X
Negative No correlation Positive
-1 0 1
-0.12
The negative correlation (r = -0.12) indicates that when Hubble increases, % of ECSA Outcomes tends to decrease.
Fitted Line Plot for Linear Model
Y = 0.5956 - 0.1705 X
% of ECSA Outcomes
100.000%
50.000%
0.000%
-50.000%
0.00 0.25 0.50 0.75 1.00
Hubble
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 0.5956 - 0.1705 X
If the model fits the data well, this equation can be used to predict % of ECSA Outcomes for a value of Hubble, or find the settings for Hubble that correspond to a desired value or range of values for % of ECSA Outcomes.
A statistically significant relationship does not imply that X causes Y.


Regression for Yes Outcome vs Theater Battle Management Core
Summary Report
Y: Yes Outcome
X: Theater Battle Management Core
Is there a relationship between Y and X?
0 0.05 0.1 > 0.5
Yes
No
P = 0.037
The relationship between Yes Outcome and Theater Battle Management Core is statistically significant (p < 0.05).
% of variation accounted for by model
0%
100%
R-sq (adj) = 0.72%
0.72% of the variation in Yes Outcome can be accounted for by the regression model.
Correlation between Y and X
Negative
No correlation
Positive
-1
0
1
-0.10
The negative correlation (r = -0.10) indicates that when Theater Battle Management Core increases, Yes Outcome tends to decrease.
Fitted Line Plot for Linear Model
Y = 5.695 - 1.028 X
Yes Outcome
7.5
5.0
2.5
0.0
0.00
0.25
0.50
0.75
1.00
Theater Battle Management Core
Comments
The fitted equation for the linear model that describes the relationship between Y and X is:
Y = 5.695 - 1.028 X
If the model fits the data well, this equation can be used to predict Yes Outcome for a value of Theater Battle Management Core, or find the settings for Theater Battle Management Core that correspond to a desired value or range of values for Yes Outcome.
A statistically significant relationship does not imply that X causes Y.

Predictor: Discipline – Aeronautical







Binary regression of Aeronautical Discpline Per Year

Performs Critical Functions - Y	1	31	(Event)
	0	26	
	Total	57	

Logistic Regression Table

Predictor	Coef	SE Coef	Z	P	Odds Ratio	95% CI Lower	Upper
Constant	0.154151	0.393398	0.39	0.695			
Year							
2012	0.297834	0.623320	0.48	0.633	1.35	0.40	4.57
2013	-0.308301	0.681385	-0.45	0.651	0.73	0.19	2.79

Log-Likelihood = -38.946
Test that all slopes are zero: G = 0.688, DF = 2, P-Value = 0.709
Measures of Association:

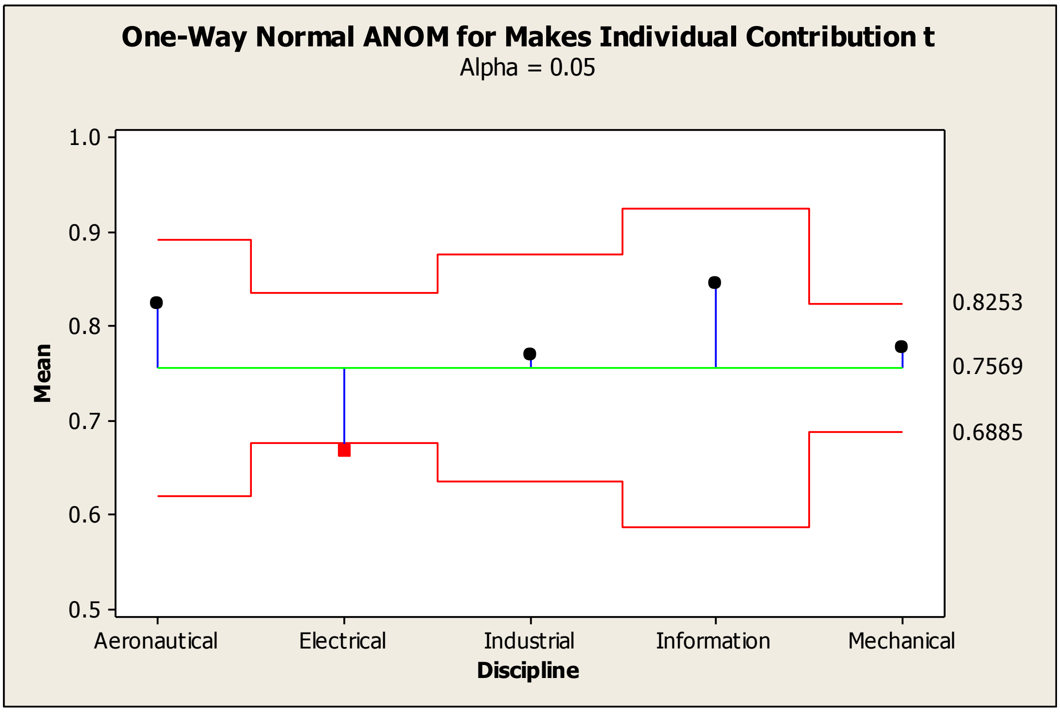
(Between the Response Variable and Predicted Probabilities)

Pairs	Number	Percent	Summary Measures	
Concordant	307	38.1	Somers' D	0.12
Discordant	212	26.3	Goodman-Kruskal Gamma	0.18

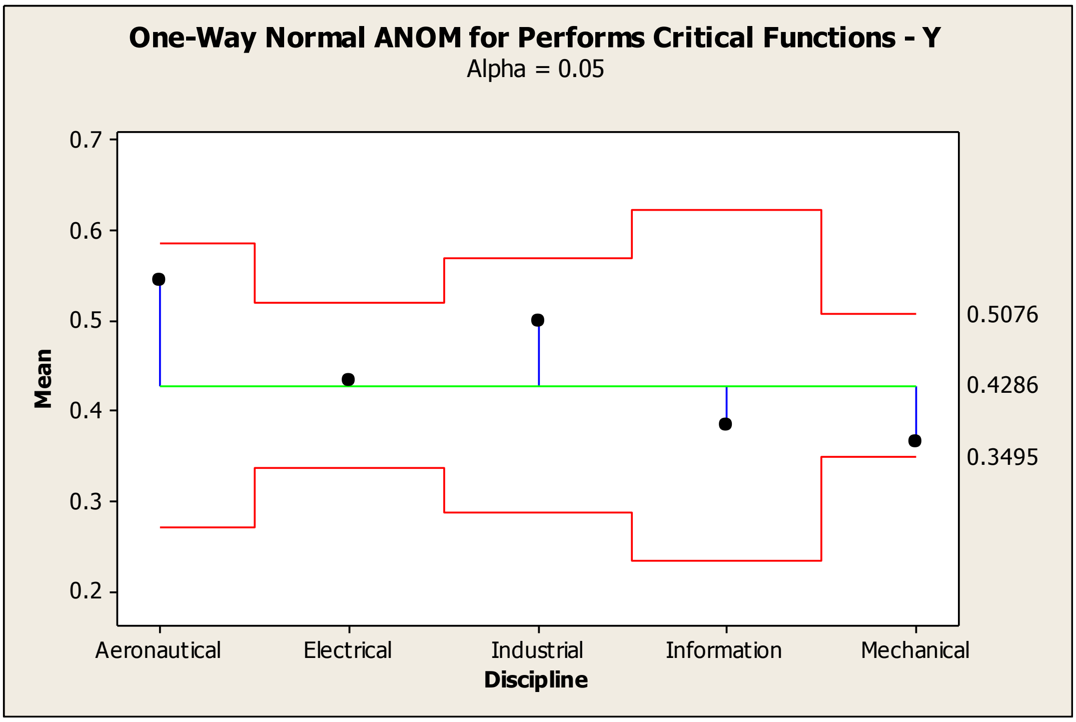
```
Ties            287      35.6  Kendall's Tau-a        0.06
Total           806     100.0
```

Comparison by ECSA ELO 8 requirement:

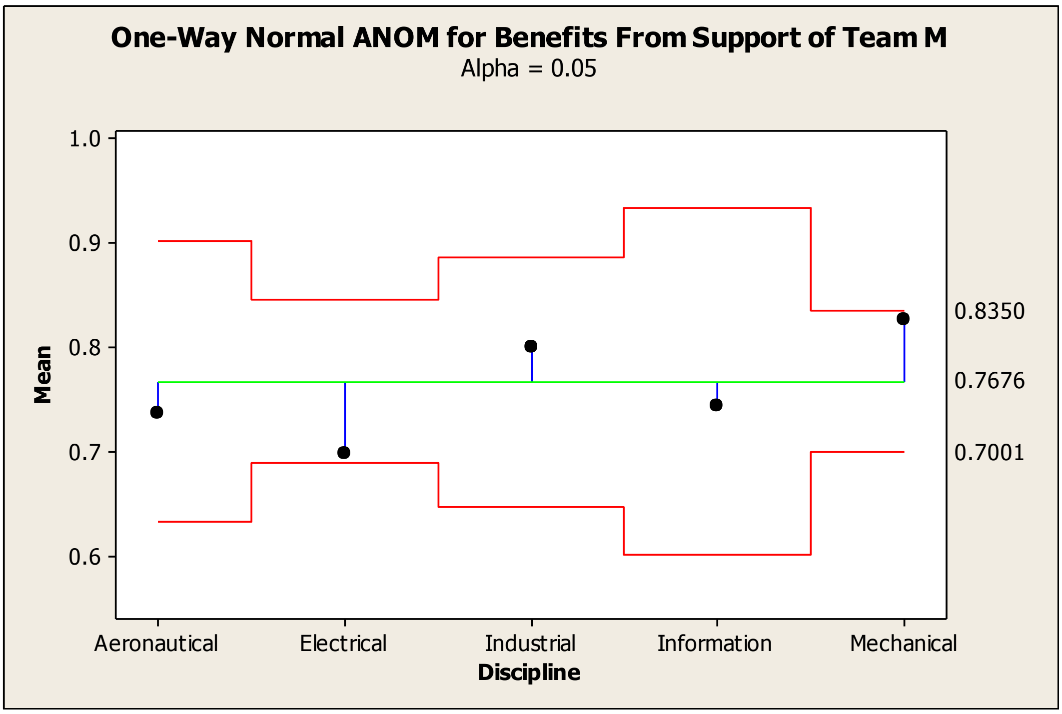
Individual Contribution to Team:



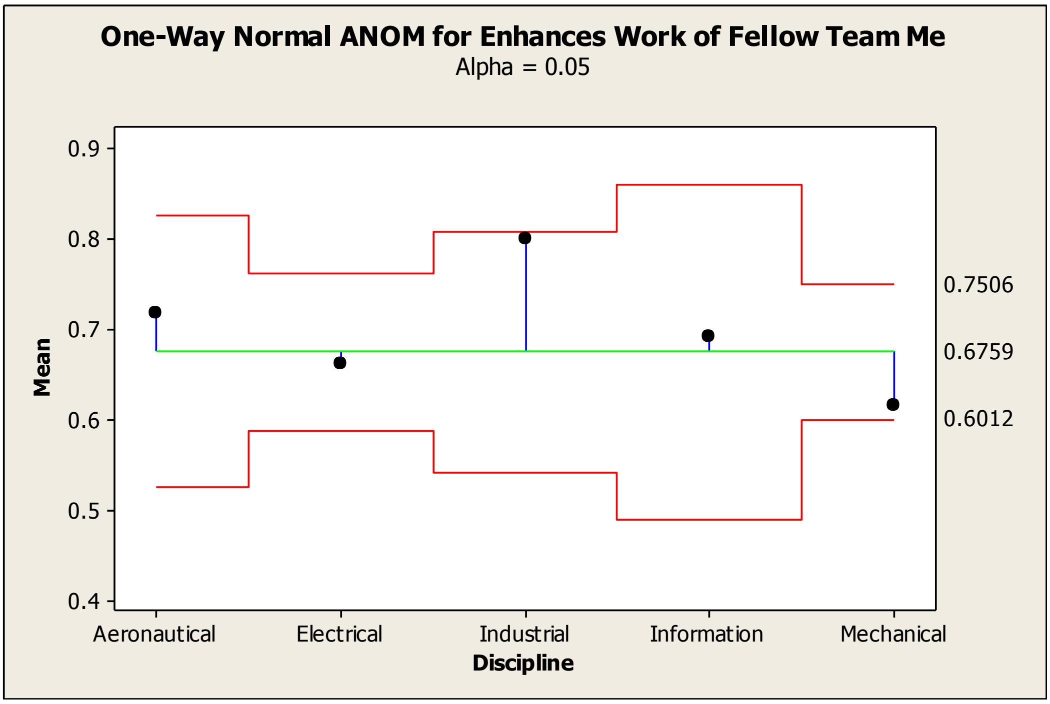
Performs Critical Functions



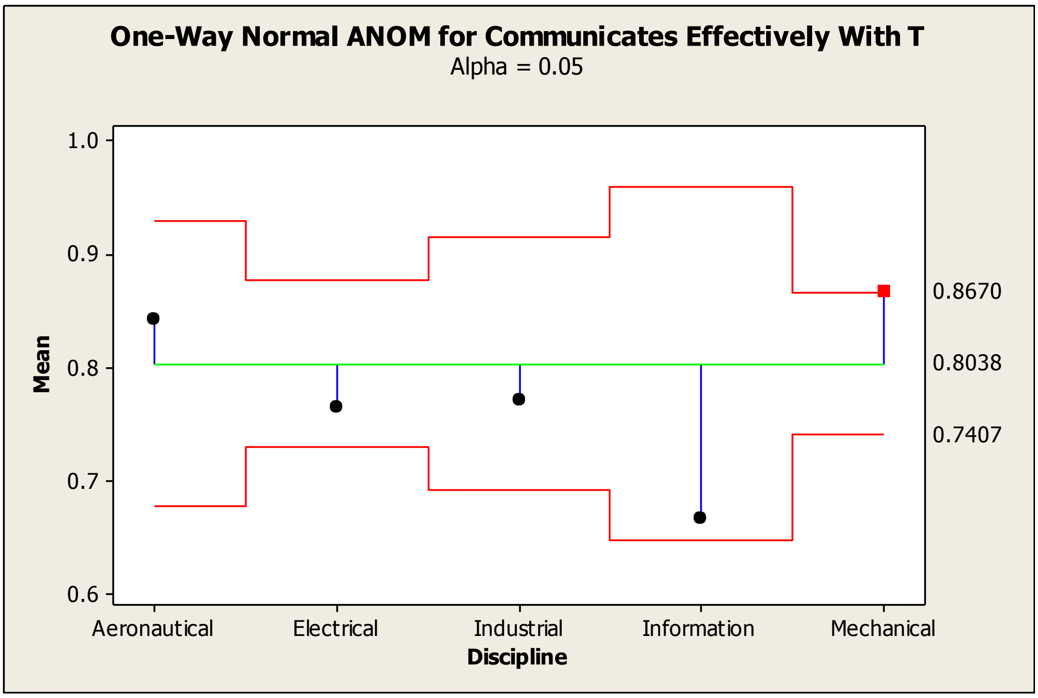
Benefits from Support of Team Members



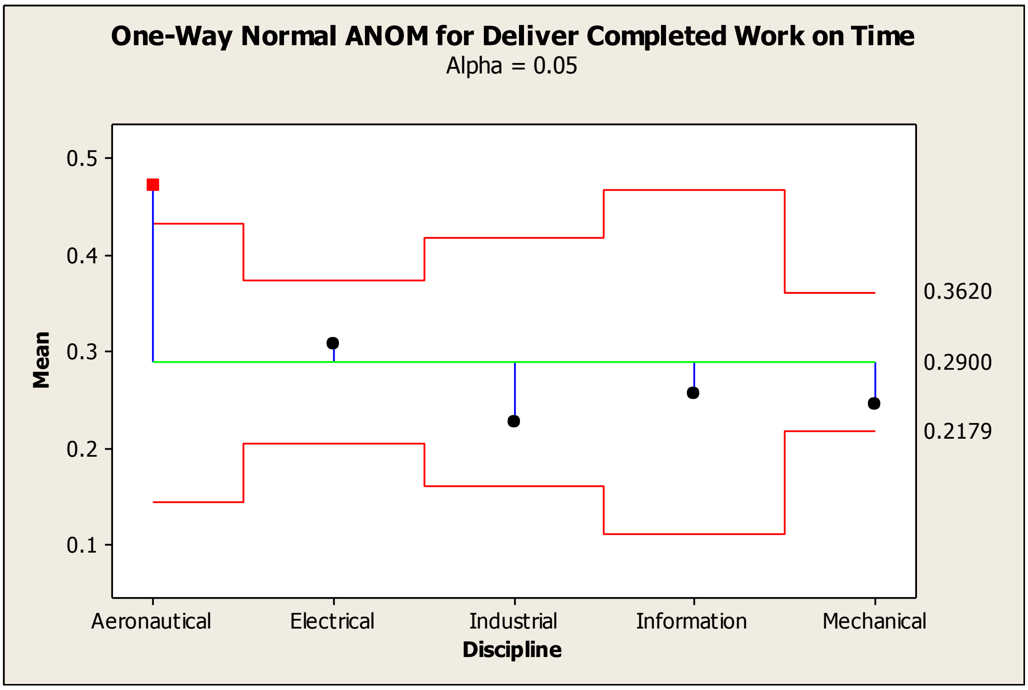
Enhances Work of Team Members



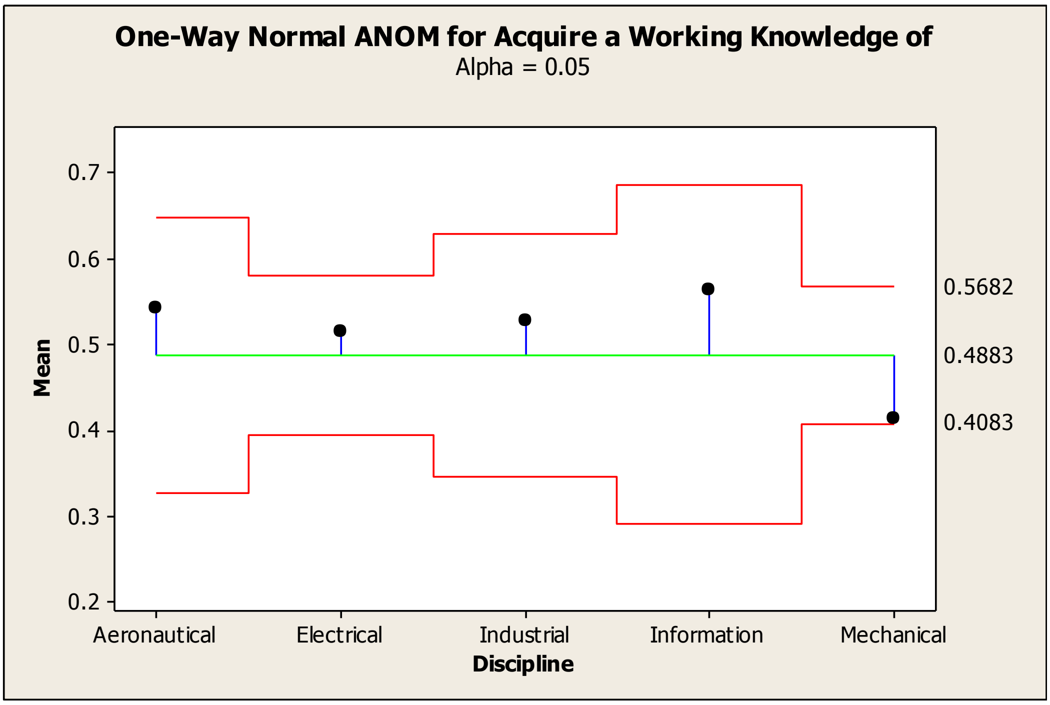
Communicates Effectively with Team Members



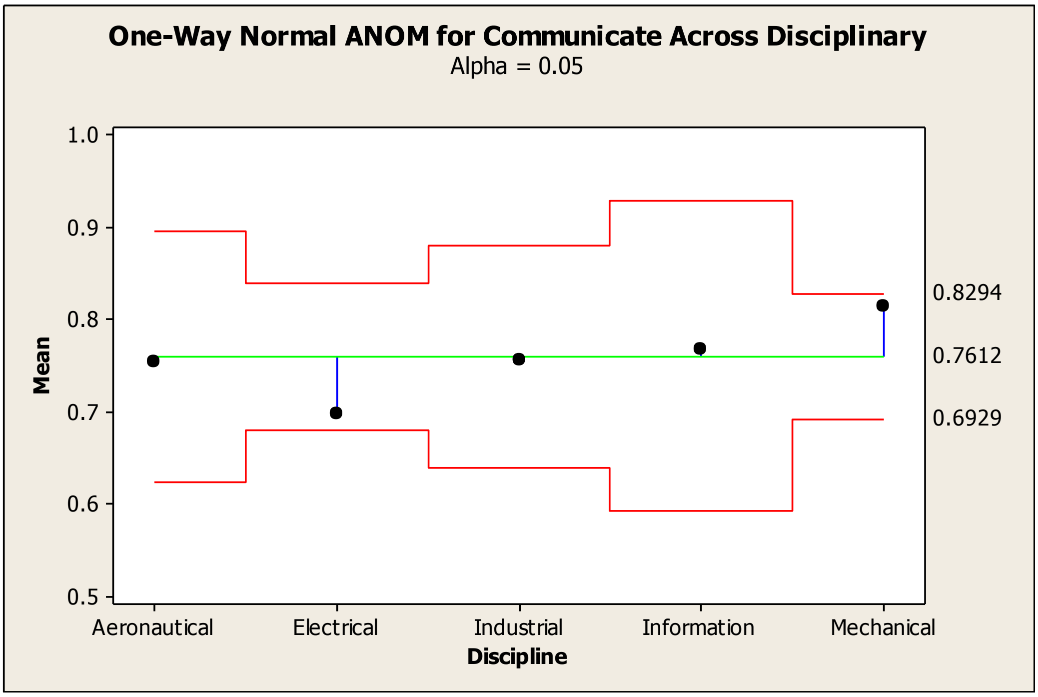
Deliver Completed Work on Time



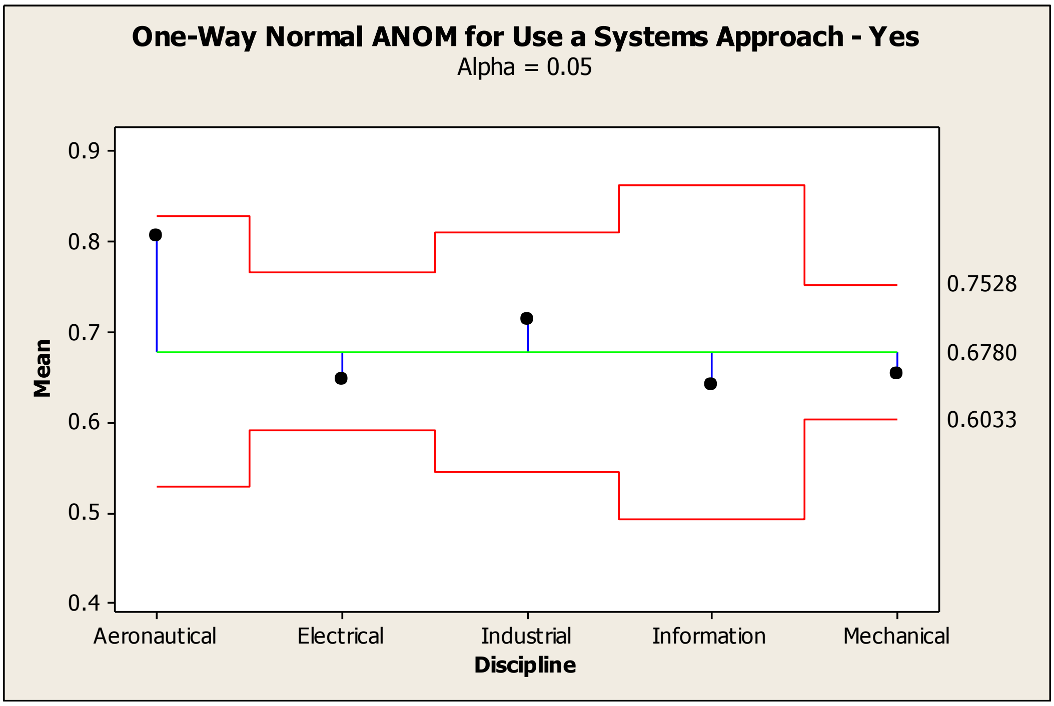
Acquire a working knowledge of co-workers discipline:



Communicate Across Disciplinary Boundaries



Use a systems approach:



Appendix F – Inferential statistics

Inference Table for Makes Individual Contributions to Group

Statistical Variables	
Total Population Size	415
Yes	356
Proportion of Yes	85.78%
Upper Sample Limit check	0.8578
Lower Sample Limit Check	0.8578
Standard Deviation of Sampling distribution	0.0171
Assumptions	
n(1-p)≥15	59
np≥15	356
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	82.42%
95% Upper Confidence Limit	89.14%
90% Lower Confidence Limit	82.96%
90% Upper Confidence Limit	88.60%
99% Lower Confidence Limit	81.37%
99% Upper Confidence Limit	81.37%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	85.44%
95% Lower Confidence Limit	82.06%
95% Upper Confidence Limit	88.82%
90% Lower Confidence Limit	82.61%
90% Upper Confidence Limit	88.28%
99% Lower Confidence Limit	81.00%
99% Upper Confidence Limit	89.88%

Score Confidence Interval	
Yes Proportion	85.78%
95% Lower Confidence Limit	82.09%
95% Upper Confidence Limit	88.82%
90% Lower Confidence Limit	82.73%
90% Upper Confidence Limit	88.37%
99% Lower Confidence Limit	80.80%
99% Upper Confidence Limit	89.64%

Makes Individual Contribution - Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	356
Proportion of Yes	75.74%
Upper Sample Limit check	0.7574
Lower Sample Limit Check	0.7574
Standard Deviation of Sampling distribution	0.0198
Assumptions	
n(1-p)≥15	114
np≥15	356
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	71.87%
95% Upper Confidence Limit	79.62%
90% Lower Confidence Limit	71.87%
90% Upper Confidence Limit	79.00%
99% Lower Confidence Limit	70.65%
99% Upper Confidence Limit	80.84%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	75.53%
95% Lower Confidence Limit	71.66%
95% Upper Confidence Limit	79.40%
90% Lower Confidence Limit	72.28%
90% Upper Confidence Limit	78.78%
99% Lower Confidence Limit	70.44%
99% Upper Confidence Limit	80.61%

Score Confidence Interval	
Proportion Value	75.74%
95% Lower Confidence Limit	71.67%
95% Upper Confidence Limit	79.40%
90% Lower Confidence Limit	72.35%
90% Upper Confidence Limit	78.84%
99% Lower Confidence Limit	70.32%
99% Upper Confidence Limit	80.46%

Inference Table for Performs Critical Functions for Not Clear

Statistical Variables	
Total Population Size	251
Yes	201
Proportion of Yes	80.08%
Upper Sample Limit check	0.8008
Lower Sample Limit Check	0.8008
Standard Deviation of Sampling distribution	0.0252
Assumptions	
n(1-p)≥15	50
np≥15	201
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	75.14%
95% Upper Confidence Limit	75.14%
90% Lower Confidence Limit	75.14%
90% Upper Confidence Limit	84.23%
99% Lower Confidence Limit	73.59%
99% Upper Confidence Limit	86.57%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	79.61%
95% Lower Confidence Limit	74.66%
95% Upper Confidence Limit	84.55%
90% Lower Confidence Limit	75.46%
90% Upper Confidence Limit	83.76%
99% Lower Confidence Limit	73.11%
99% Upper Confidence Limit	86.11%

Score Confidence Interval	
Score Confidence Interval	80.08%
95% Lower Confidence Limit	74.70%
95% Upper Confidence Limit	84.55%
90% Lower Confidence Limit	75.62%
90% Upper Confidence Limit	83.90%
99% Lower Confidence Limit	72.85%
99% Upper Confidence Limit	85.76%

Performs Critical Functions – Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	201
Proportion of Yes	42.77%
Upper Sample Limit check	0.4277
Lower Sample Limit Check	0.4277
Standard Deviation of Sampling distribution	0.0228
Assumptions	
n(1-p)≥15	269
np≥15	201
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	38.29%
95% Upper Confidence Limit	38.29%
90% Lower Confidence Limit	38.29%
90% Upper Confidence Limit	46.52%
99% Lower Confidence Limit	36.89%
99% Upper Confidence Limit	48.64%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	42.83%
95% Lower Confidence Limit	38.37%
95% Upper Confidence Limit	47.28%
90% Lower Confidence Limit	39.09%
90% Upper Confidence Limit	46.57%
99% Lower Confidence Limit	36.97%
99% Upper Confidence Limit	48.68%

Score Confidence Interval	
Proportion Value	42.77%
95% Lower Confidence Limit	38.37%
95% Upper Confidence Limit	47.28%
90% Lower Confidence Limit	39.06%
90% Upper Confidence Limit	46.55%
99% Lower Confidence Limit	37.03%
99% Upper Confidence Limit	48.71%

Inference Table for Enhances Work of Fellow Team Members

Statistical Variables	
Total Sample Size	397
Yes	317
Proportion of Yes	79.85%
Upper Sample Limit check	79.85%
Lower Sample Limit Check	79.85%
Standard Deviation of Sampling distribution	0.0201
Assumptions	
n(1-p)≥15	80
np≥15	317
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	75.90%
95% Upper Confidence Limit	75.90%
90% Lower Confidence Limit	75.90%
90% Upper Confidence Limit	83.16%
99% Lower Confidence Limit	74.66%
99% Upper Confidence Limit	85.03%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	79.55%
95% Lower Confidence Limit	75.60%
95% Upper Confidence Limit	83.50%
90% Lower Confidence Limit	76.24%
90% Upper Confidence Limit	82.86%
99% Lower Confidence Limit	74.36%
99% Upper Confidence Limit	84.74%

Score Confidence Interval	
Score Confidence Interval	79.84%
95% Lower Confidence Limit	75.63%
95% Upper Confidence Limit	83.50%
90% Lower Confidence Limit	76.34%
90% Upper Confidence Limit	82.95%
99% Lower Confidence Limit	74.19%
99% Upper Confidence Limit	84.52%

Enhances Work of Team Members - Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	317
Proportion of Yes	67.45%
Upper Sample Limit check	0.6745
Lower Sample Limit Check	0.6745
Standard Deviation of Sampling distribution	0.0216
Assumptions	
n(1-p)≥15	153
np≥15	317
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	63.21%
95% Upper Confidence Limit	63.21%
90% Lower Confidence Limit	67.45%
90% Upper Confidence Limit	71.00%
99% Lower Confidence Limit	61.88%
99% Upper Confidence Limit	73.01%

ilsons Adjusted Confidence Interval	
Adjusted proportion value	67.30%
95% Lower Confidence Limit	63.08%
95% Upper Confidence Limit	71.52%
90% Lower Confidence Limit	63.76%
90% Upper Confidence Limit	70.84%
99% Lower Confidence Limit	61.75%
99% Upper Confidence Limit	72.85%

Score Confidence Interval	
Proportion Value	67.45%
95% Lower Confidence Limit	63.08%
95% Upper Confidence Limit	71.53%
90% Lower Confidence Limit	63.80%
90% Upper Confidence Limit	70.89%
99% Lower Confidence Limit	61.67%
99% Upper Confidence Limit	72.74%

Inference Table for Benefits from Support of Team Members

Statistical Variables	
Total Sample Size	420
Yes	361
Proportion of Yes	85.95%
Upper Sample Limit check	85.95%
Lower Sample Limit Check	85.95%
Standard Deviation of Sampling distribution	0.0170
Assumptions	
n(1-p)≥15	59
np≥15	361
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	82.63%
95% Upper Confidence Limit	82.63%
90% Lower Confidence Limit	82.63%
90% Upper Confidence Limit	88.74%
99% Lower Confidence Limit	81.58%
99% Upper Confidence Limit	90.32%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	85.61%
95% Lower Confidence Limit	82.27%
95% Upper Confidence Limit	88.95%
90% Lower Confidence Limit	82.81%
90% Upper Confidence Limit	88.42%
99% Lower Confidence Limit	81.22%
99% Upper Confidence Limit	90.00%

Score Confidence Interval	
Score Confidence Interval	85.95%
95% Lower Confidence Limit	82.30%
95% Upper Confidence Limit	88.95%
90% Lower Confidence Limit	82.93%
90% Upper Confidence Limit	88.51%
99% Lower Confidence Limit	81.02%
99% Upper Confidence Limit	89.76%

Benefits from Support of Team Members – Population Inference

Statistical Variables	
Total Population Size	470
Yes	361
Proportion of Yes	76.81%
Upper Sample Limit check	0.7681
Lower Sample Limit Check	0.7681
Standard Deviation of Sampling distribution	0.0195
Assumptions	
n(1-p)≥15	109
np≥15	361
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	72.99%
95% Upper Confidence Limit	80.62%
90% Lower Confidence Limit	73.61%
90% Upper Confidence Limit	80.01%
99% Lower Confidence Limit	71.79%
99% Upper Confidence Limit	71.79%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	76.58%
95% Lower Confidence Limit	72.77%
95% Upper Confidence Limit	80.39%
90% Lower Confidence Limit	73.38%
90% Upper Confidence Limit	79.78%
99% Lower Confidence Limit	71.57%
99% Upper Confidence Limit	81.59%

Score Confidence Interval	
Yes Proportion	76.81%
95% Lower Confidence Limit	72.78%
95% Upper Confidence Limit	80.40%
90% Lower Confidence Limit	73.46%
90% Upper Confidence Limit	79.85%
99% Lower Confidence Limit	71.44%
99% Upper Confidence Limit	81.43%

Inference Table for Communicates Effectively with Team Members

Statistical Variables	
Total Sample Size	420
Yes	361
Proportion of Yes	85.95%
Upper Sample Limit check	85.95%
Lower Sample Limit Check	85.95%
Standard Deviation of Sampling distribution	0.0170
Assumptions	
n(1-p)≥15	59
np≥15	361
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	82.63%
95% Upper Confidence Limit	82.63%
90% Lower Confidence Limit	82.63%
90% Upper Confidence Limit	88.74%
99% Lower Confidence Limit	81.58%
99% Upper Confidence Limit	90.32%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	85.61%
95% Lower Confidence Limit	82.27%
95% Upper Confidence Limit	88.95%
90% Lower Confidence Limit	82.81%
90% Upper Confidence Limit	88.42%
99% Lower Confidence Limit	81.22%
99% Upper Confidence Limit	90.00%

Score Confidence Interval	
Yes Proportion	85.95%
95% Lower Confidence Limit	82.30%
95% Upper Confidence Limit	88.95%
90% Lower Confidence Limit	82.93%
90% Upper Confidence Limit	88.51%
99% Lower Confidence Limit	81.02%
99% Upper Confidence Limit	89.76%

Communicates Effectively with Team Members – Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	378
Proportion of Yes	80.43%
Upper Sample Limit check	0.8043
Lower Sample Limit Check	0.8043
Standard Deviation of Sampling distribution	0.0183
Assumptions	
n(1-p)≥15	92
np≥15	378
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	76.84%
95% Upper Confidence Limit	84.01%
90% Lower Confidence Limit	76.84%
90% Upper Confidence Limit	83.44%
99% Lower Confidence Limit	75.71%
99% Upper Confidence Limit	85.14%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	80.17%
95% Lower Confidence Limit	76.58%
95% Upper Confidence Limit	83.76%
90% Lower Confidence Limit	77.16%
90% Upper Confidence Limit	83.18%
99% Lower Confidence Limit	75.45%
99% Upper Confidence Limit	84.89%

Score Confidence Interval	
Proportion Value	80.43%
95% Lower Confidence Limit	76.60%
95% Upper Confidence Limit	83.76%
90% Lower Confidence Limit	77.24%
90% Upper Confidence Limit	83.26%
99% Lower Confidence Limit	75.30%
99% Upper Confidence Limit	84.70%

Inference Table for Deliver Completed Work on Time

Statistical Variables	
Total Sample Size	174
Yes	136
Proportion of Yes	78.16%
Upper Sample Limit check	78.16%
Lower Sample Limit Check	78.16%
Standard Deviation of Sampling distribution	0.0313
Assumptions	
n(1-p)≥15	38
np≥15	136
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	72.02%
95% Upper Confidence Limit	72.02%
90% Lower Confidence Limit	72.02%
90% Upper Confidence Limit	83.31%
99% Lower Confidence Limit	70.09%
99% Upper Confidence Limit	86.23%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	77.53%
95% Lower Confidence Limit	71.40%
95% Upper Confidence Limit	83.66%
90% Lower Confidence Limit	72.38%
90% Upper Confidence Limit	82.67%
99% Lower Confidence Limit	69.47%
99% Upper Confidence Limit	85.59%

Score Confidence Interval	
Yes Proportion	78.16%
95% Lower Confidence Limit	71.45%
95% Upper Confidence Limit	83.66%
90% Lower Confidence Limit	72.60%
90% Upper Confidence Limit	82.86%
99% Lower Confidence Limit	69.14%
99% Upper Confidence Limit	85.11%

Deliver Completed Work on Time – Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	136
Proportion of Yes	28.94%
Upper Sample Limit check	0.2894
Lower Sample Limit Check	0.2894
Standard Deviation of Sampling distribution	0.0209
Assumptions	
n(1-p)≥15	334
np≥15	136
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	24.84%
95% Upper Confidence Limit	24.84%
90% Lower Confidence Limit	24.84%
90% Upper Confidence Limit	32.38%
99% Lower Confidence Limit	23.55%
99% Upper Confidence Limit	34.32%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	29.11%
95% Lower Confidence Limit	25.02%
95% Upper Confidence Limit	33.20%
90% Lower Confidence Limit	25.68%
90% Upper Confidence Limit	32.55%
99% Lower Confidence Limit	23.74%
99% Upper Confidence Limit	34.49%

Score Confidence Interval	
Proportion Value	28.94%
95% Lower Confidence Limit	25.02%
95% Upper Confidence Limit	33.19%
90% Lower Confidence Limit	25.62%
90% Upper Confidence Limit	32.49%
99% Lower Confidence Limit	23.87%
99% Upper Confidence Limit	34.59%

Deliver Completed Work on Time – Population Inference

Statistical Variables	
Total Sample Size	443
Yes	229
Proportion of Yes	51.69%
Upper Sample Limit check	51.69%
Lower Sample Limit Check	51.69%
Standard Deviation of Sampling distribution	0.0237
Assumptions	
n(1-p)≥15	214
np≥15	229
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	47.04%
95% Upper Confidence Limit	47.04%
90% Lower Confidence Limit	47.04%
90% Upper Confidence Limit	55.60%
99% Lower Confidence Limit	45.58%
99% Upper Confidence Limit	57.81%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	51.68%
95% Lower Confidence Limit	47.05%
95% Upper Confidence Limit	56.31%
90% Lower Confidence Limit	47.79%
90% Upper Confidence Limit	55.57%
99% Lower Confidence Limit	45.59%
99% Upper Confidence Limit	57.77%

Score Confidence Interval	
Yes Proportion	51.69%
95% Lower Confidence Limit	47.05%
95% Upper Confidence Limit	56.31%
90% Lower Confidence Limit	47.79%
90% Upper Confidence Limit	55.58%
99% Lower Confidence Limit	45.60%
99% Upper Confidence Limit	57.74%

Deliver Completed Work on Time – Population Inference

Statistical Variables	
Total Population Size	470
Yes	229
Proportion of Yes	48.72%
Upper Sample Limit check	0.4872
Lower Sample Limit Check	0.4872
Standard Deviation of Sampling distribution	0.0231
Assumptions	
n(1-p)≥15	241
np≥15	229
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	44.20%
95% Upper Confidence Limit	53.24%
90% Lower Confidence Limit	44.93%
90% Upper Confidence Limit	52.52%
99% Lower Confidence Limit	42.78%
99% Upper Confidence Limit	42.78%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	48.73%
95% Lower Confidence Limit	44.23%
95% Upper Confidence Limit	53.23%
90% Lower Confidence Limit	44.96%
90% Upper Confidence Limit	52.51%
99% Lower Confidence Limit	42.82%
99% Upper Confidence Limit	54.65%

Score Confidence Interval	
Yes Proportion	48.72%
95% Lower Confidence Limit	44.23%
95% Upper Confidence Limit	53.23%
90% Lower Confidence Limit	44.95%
90% Upper Confidence Limit	52.51%
99% Lower Confidence Limit	42.84%
99% Upper Confidence Limit	54.64%

Inference Table for Communicate Across a Disciplinary Boundary

Statistical Variables	
Total Sample Size	442
Yes	358
Proportion of Yes	81.00%
Upper Sample Limit check	81.00%
Lower Sample Limit Check	81.00%
Standard Deviation of Sampling distribution	0.0187
Assumptions	
n(1-p)≥15	84
np≥15	358
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	77.34%
95% Upper Confidence Limit	84.65%
90% Lower Confidence Limit	77.34%
90% Upper Confidence Limit	84.07%
99% Lower Confidence Limit	76.19%
99% Upper Confidence Limit	85.80%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	80.72%
95% Lower Confidence Limit	77.06%
95% Upper Confidence Limit	84.38%
90% Lower Confidence Limit	77.64%
90% Upper Confidence Limit	83.79%
99% Lower Confidence Limit	75.91%
99% Upper Confidence Limit	85.53%

Score Confidence Interval	
Yes Proportion	81.00%
95% Lower Confidence Limit	77.08%
95% Upper Confidence Limit	84.38%
90% Lower Confidence Limit	77.74%
90% Upper Confidence Limit	83.87%
99% Lower Confidence Limit	75.74%
99% Upper Confidence Limit	85.33%

Deliver Completed Work on Time – Population Inference

Statistical Variables	
Total Population Size	470
Yes	358
Proportion of Yes	76.17%
Upper Sample Limit check	0.7617
Lower Sample Limit Check	0.7617
Standard Deviation of Sampling distribution	0.0197
Assumptions	
n(1-p)≥15	112
np≥15	358
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	72.32%
95% Upper Confidence Limit	80.02%
90% Lower Confidence Limit	72.32%
90% Upper Confidence Limit	79.40%
99% Lower Confidence Limit	71.11%
99% Upper Confidence Limit	81.23%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	75.95%
95% Lower Confidence Limit	72.10%
95% Upper Confidence Limit	79.80%
90% Lower Confidence Limit	72.72%
90% Upper Confidence Limit	79.18%
99% Lower Confidence Limit	70.89%
99% Upper Confidence Limit	81.01%

Score Confidence Interval	
Proportion Value	76.17%
95% Lower Confidence Limit	72.12%
95% Upper Confidence Limit	79.80%
90% Lower Confidence Limit	72.79%
90% Upper Confidence Limit	79.25%
99% Lower Confidence Limit	70.77%
99% Upper Confidence Limit	80.85%

Inference Table for Uses a Systems Approach

Statistical Variables	
Total Sample Size	447
Yes	319
Proportion of Yes	71.36%
Upper Sample Limit check	71.36%
Lower Sample Limit Check	71.36%
Standard Deviation of Sampling distribution	0.0214
Assumptions	
n(1-p)≥15	128
np≥15	319
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	67.17%
95% Upper Confidence Limit	75.56%
90% Lower Confidence Limit	67.17%
90% Upper Confidence Limit	74.88%
99% Lower Confidence Limit	65.86%
99% Upper Confidence Limit	76.87%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	71.18%
95% Lower Confidence Limit	66.99%
95% Upper Confidence Limit	75.36%
90% Lower Confidence Limit	67.67%
90% Upper Confidence Limit	74.68%
99% Lower Confidence Limit	65.68%
99% Upper Confidence Limit	76.67%

Score Confidence Interval	
Yes Proportion	71.36%
95% Lower Confidence Limit	67.01%
95% Upper Confidence Limit	75.36%
90% Lower Confidence Limit	67.73%
90% Upper Confidence Limit	74.75%
99% Lower Confidence Limit	65.58%
99% Upper Confidence Limit	76.53%

Uses a Systems Approach – Population Inference

Wald Confidence Interval	
Total Population Size	470
Yes	319
Proportion of Yes	67.87%
Upper Sample Limit check	0.6787
Lower Sample Limit Check	0.6787
Standard Deviation of Sampling distribution	0.0215

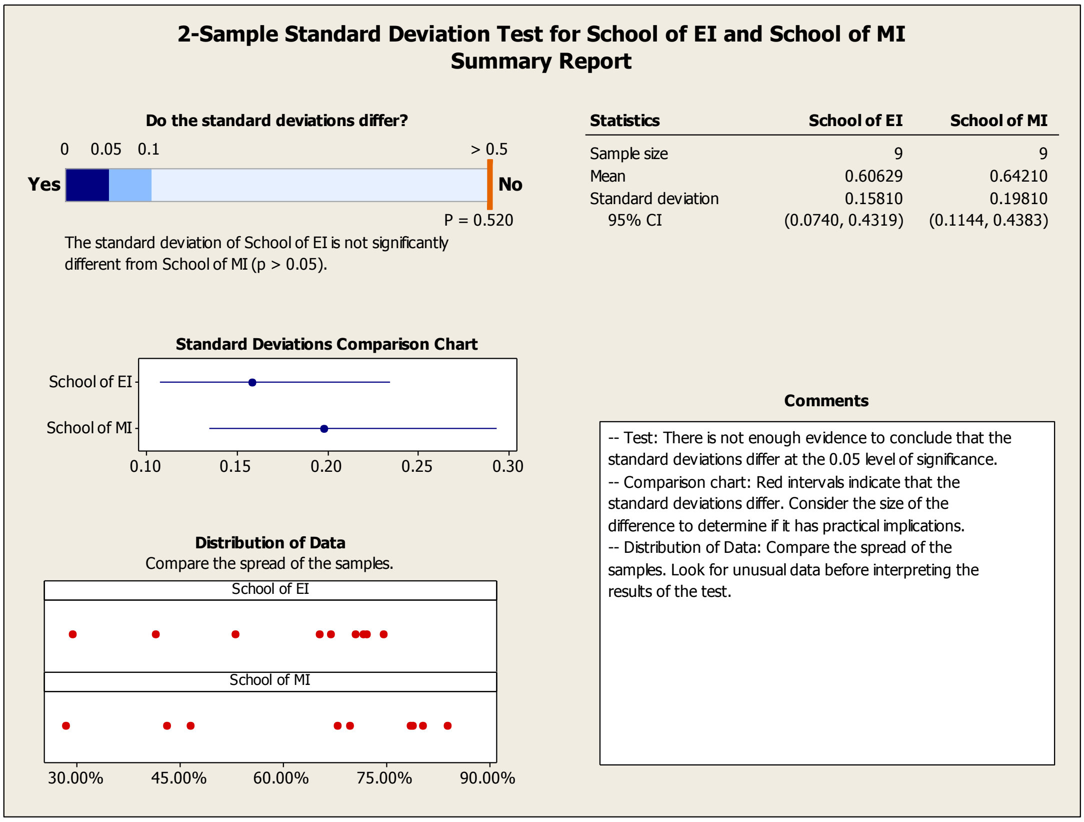
Assumptions	
n(1-p)≥15	151
np≥15	319
Confidence Intervals (Varying values of Alpha)	
95% Lower Confidence Limit	63.65%
95% Upper Confidence Limit	72.09%
90% Lower Confidence Limit	63.65%
90% Upper Confidence Limit	71.42%
99% Lower Confidence Limit	62.32%
99% Upper Confidence Limit	73.42%

Wilsons Adjusted Confidence Interval	
Adjusted proportion value	67.72%
95% Lower Confidence Limit	63.51%
95% Upper Confidence Limit	71.93%
90% Lower Confidence Limit	64.19%
90% Upper Confidence Limit	71.25%
99% Lower Confidence Limit	62.19%
99% Upper Confidence Limit	73.25%

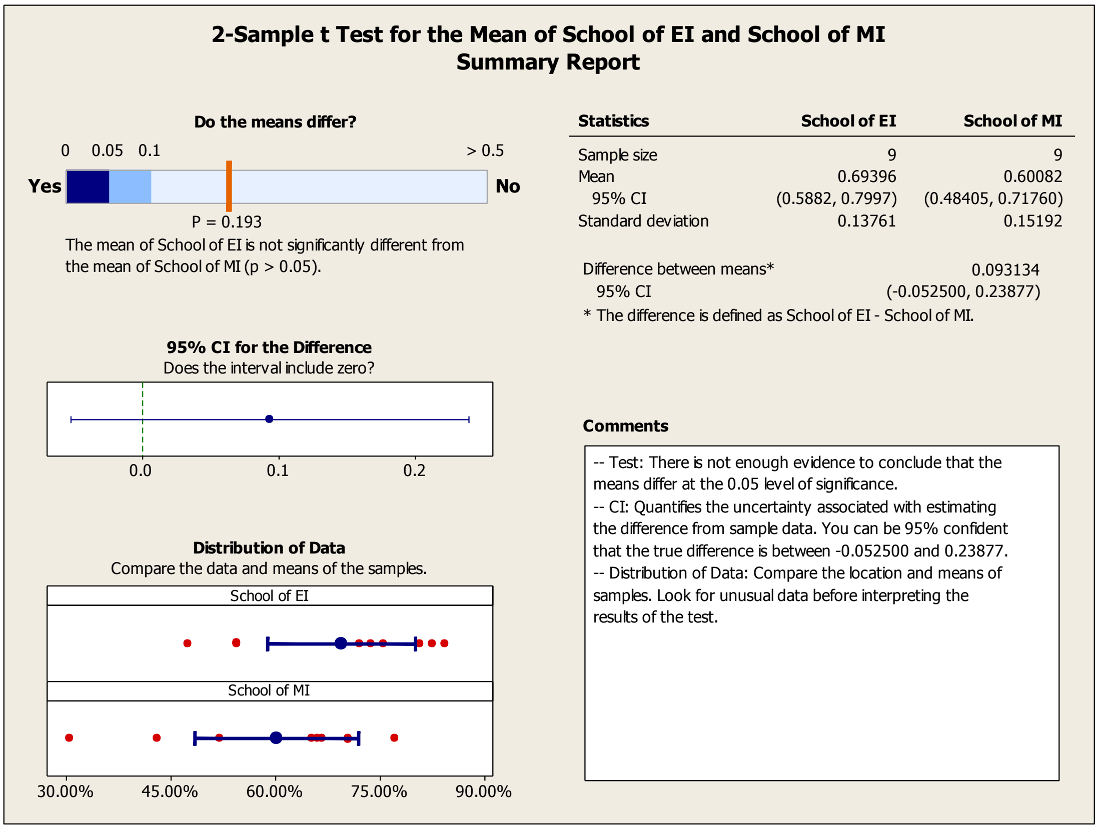
Score Confidence Interval	
Proportion Value	67.87%
95% Lower Confidence Limit	63.52%
95% Upper Confidence Limit	71.93%
90% Lower Confidence Limit	64.24%
90% Upper Confidence Limit	71.30%
99% Lower Confidence Limit	62.11%
99% Upper Confidence Limit	73.14%

Appendix G – Maximum Likelihood and ANOVA

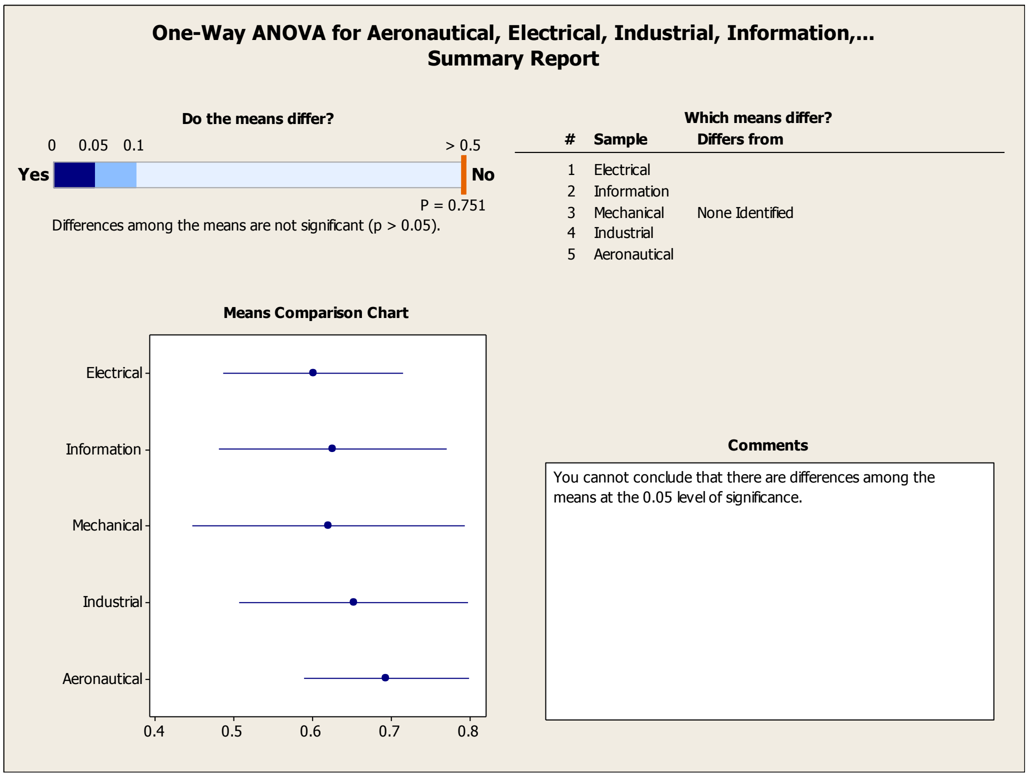
Comparison of Maximum likelihood per school:

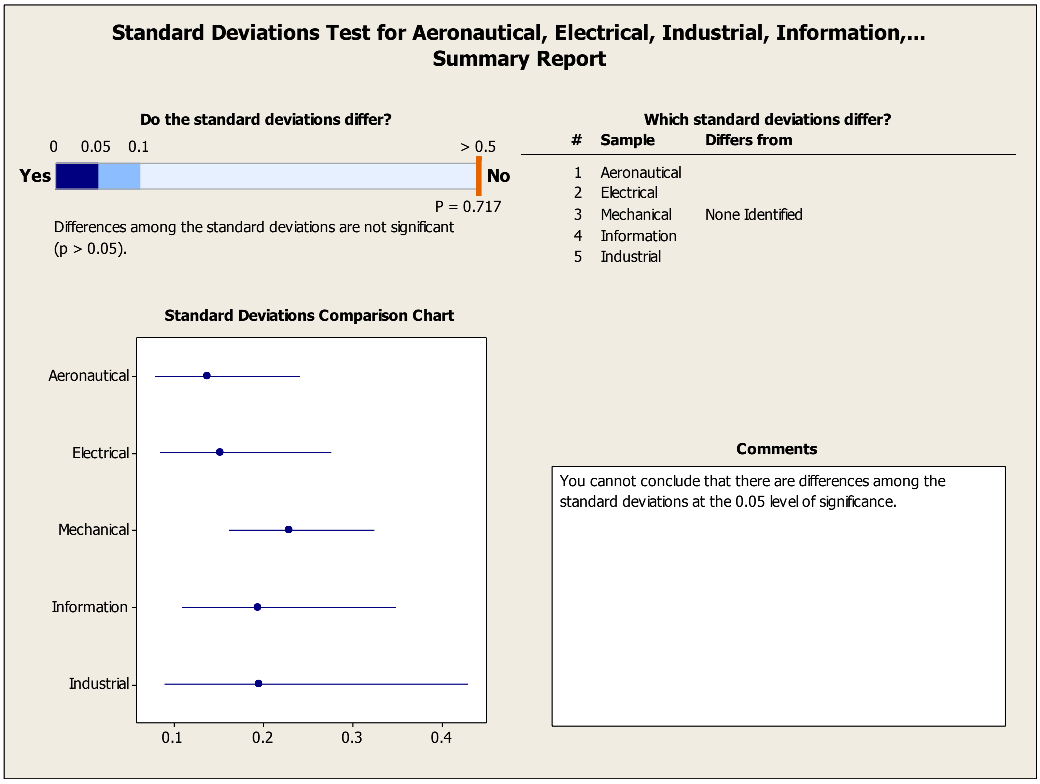


Appendix

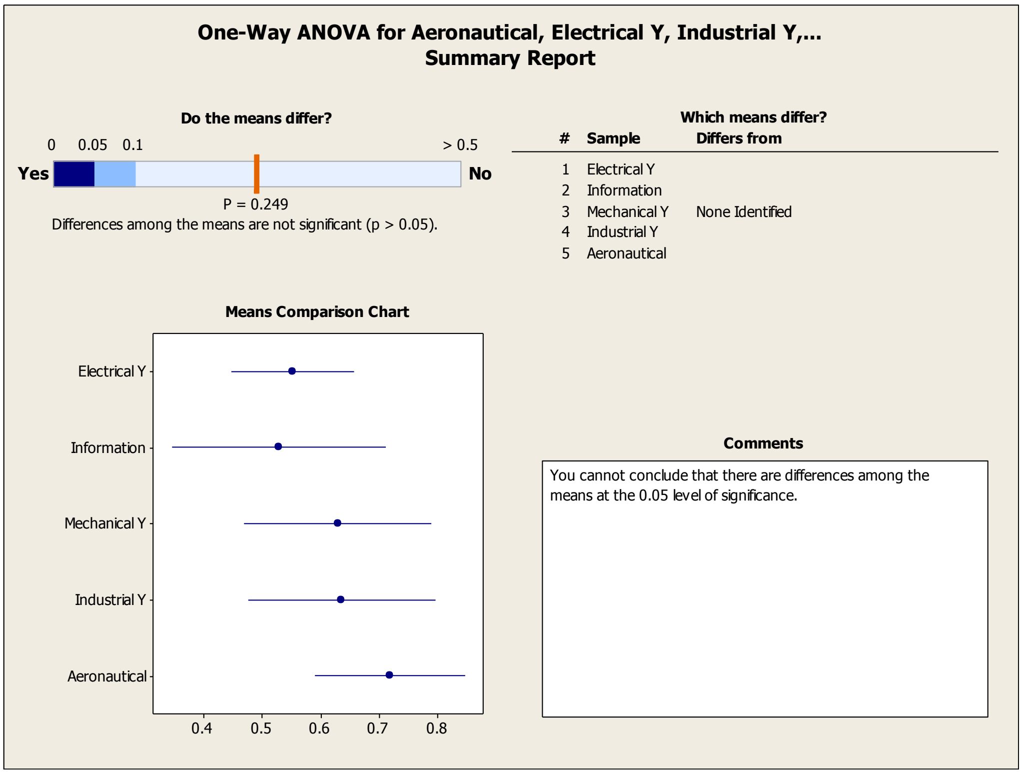


Maximum likelihood tests between disciplines:

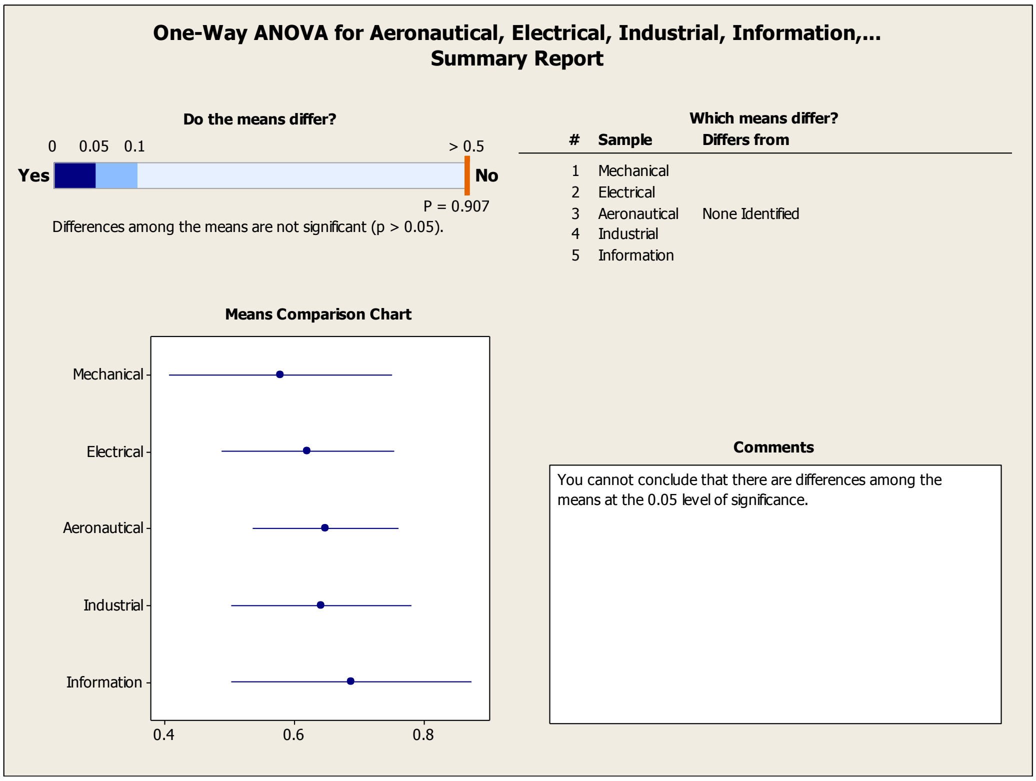




Comparison of Discipline by Year 2011.



Comparison by Year 2012



Comparison by Year 2013