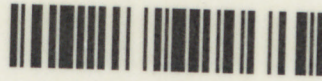


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**INTEGRATING MATHEMATICS INTO
ENGINEERING:
A CASE STUDY**

by

SHAHEED MAHOMED

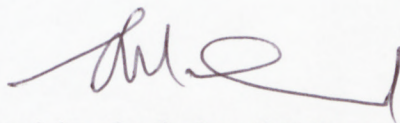
**Thesis submitted in fulfilment of the requirements for the
Magister Technologiae: Mechanical Engineering**

**in the
FACULTY of ENGINEERING
at the
CAPE PENINSULA UNIVERSITY OF TECHNOLOGY**

CAPE TOWN

January 2007

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A handwritten signature in dark ink, appearing to read 'Shaheed Mahomed', written in a cursive style.

I, Shaheed Mahomed, hereby declare that the contents of this dissertation represent my own unaided work, and that the dissertation has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

ABSTRACT

Twelve years into a democracy, South Africa still faces many developmental challenges. Since 2002 Universities of Technology in South Africa have introduced Foundational Programmes/provisions in their Science and Engineering programmes as a key mechanism for increasing throughput and enhancing quality. The Department of Education has been funding these foundational provisions since 2005. This Case Study evaluates an aspect of a Foundational provision in Mechanical Engineering, from the beginning of 2002 to the end of 2005, at a University of Technology, with a view to contributing to its improvement.

The Cape Peninsula University of Technology (CPUT), the locus for this Case Study, is the only one of its kind in a region that serves in excess of 4.5 million people. Further, under-preparedness in Mathematics for tertiary level study is a national and international phenomenon. There is thus a social interest in the evaluation of a Mathematics course that is part of a strategy towards addressing the shortage in Engineering graduates. This Evaluation of integration of the Foundation Mathematics course into Foundation Science, within the Department of Mechanical Engineering at CPUT, falls within the ambit of this social need.

An integrated approach to curriculum conception, design and implementation is a widely accepted strategy in South Africa and internationally; this approach formed the basis of the model used for the Foundation programme that formed part of this Evaluation. A review of the literature of the underpinnings of the model provided a theoretical framework for this Evaluation Study. In essence this involved the use of academic literacy theory together with learning approach theory to provide a lens for this Case Study. The research methodology used was largely qualitative, with both qualitative and quantitative methods used for purposes of triangulation. The Evaluation was conducted of four key aspects of integration of Foundation Mathematics into Foundation Science, namely conception, design, implementation and impact.

This provided the framework for the main argument of this thesis, namely that conceptual and design flaws in the integration model led to student learning of Mechanics concepts (in Foundation Science) not being effectively supported. The final section of the Study

outlines recommendations for improvement of the Foundation Mathematics course. It also identifies areas for future research.

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List of Abbreviations and definitions/descriptions

ABBR	EXPANDED	DEFINITION/DESCRIPTION
AD	ACADEMIC DEVELOPMENT	The field that is tasked with strategies of enabling students to develop their subject knowledge, academic literacies and skills in Higher Education
BTECH	BACHELORS DIPLOMA	One year programme taken after completion of the MDIPME, qualifying as technologist
CPUT	CAPE PENINSULA UNIVERSITY OF TECHNOLOGY	This is the institution resulting from the merger of the old Cape Technikon and the Peninsula Technikon on the 1 st January 2005.
CCFO's	CRITICAL CROSS FIELD OUTCOMES	Set of outcomes for Technologists agreed upon by the national Technikon sector in line with SAQA
ECSA	ENGINEERING COUNCIL OF SOUTH AFRICA	Regulatory Body by the Engineering sector in SA that oversees standards of tertiary engineering programmes
EMS	ENGINEERING MATERIALS AND SCIENCE COURSE	A course centred on the science of materials used in engineering
FM	FOUNDATION MATHEMATICS	The mathematics course in the Foundation Programme
FS	FOUNDATION SCIENCE	The Science course that is part of the Foundation Programme, mainly based on Mechanics concepts
HG	HIGHER GRADE	Higher level than Standard Grade , covers range from procedural to conceptual understanding
	LECTURER EMS L01	Lecturer of the subject EMS
	LECTURER 2002 FL01	Foundation lecturer in the year 2002
	LECTURER 2005 FL01	Foundation lecturer in the year 2005
	LECTURER MAIN L01	Lecturer who is a subject specialist in higher levels S3 and S4 of the MDIPME
	LECTURER MATHS L01	Mathematics lecturer in the Mechanical Engineering Department
	LECTURER MECH L01	Lecturer in the mainstream in a Mechanics-type subject (Mechanics or Mechanics of Machines 1 or 2)
MDIPME	NATIONAL DIPLOMA IN MECHANICAL ENGINEERING	Programme for Mechanical Engineering Technician offered by Universities of Technology-precursor to Technologist
	MAINSTREAM	Part of the MDIPME study
SAQA	SOUTH AFRICAN QUALIFICATION AUTHORITY	South African Statutory body that regulates standards for tertiary institutions, among others.
SG	STANDARD GRADE	Category of subject taken at High school that is simplified and tends to focus on routine procedures than deep conceptual

		understanding – simpler as compared to Higher Grade
S1-S4	SEMESTER1 LEVEL – SEMESTER4 LEVEL	S1 is the official first semester courses of the MDIPME, S2 are the courses from the second semester and so on up to S4
	STUDENT	Refers to a student at tertiary level unless the context indicates high school or college
	STUDENT 2002 S01	Student from focus group of the cohort of 2002
	STUDENT 2003 S01	Student from focus group of the cohort of 2003, respectively up to 2005
	STUDENT 2002 QS01	Q refers to a student response from the 2005 questionnaire, Q1 from the 2004 questionnaire and Q2 from the 2003 questionnaire (See Appendices A-C)
	TECHNIKON	Fore-runner of the Universities of Technology in South Africa
	'WALK THE PLANK'	Students have to make a public defence of their results, facing questions from lecturers and fellow students

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INTEGRATING MATHEMATICS INTO ENGINEERING: A CASE STUDY

CHAPTER 1

INTRODUCTION

1.1. Main thesis statement

This thesis presents the findings of a four year case study which evaluated an 'integrated' Mathematics component of a Foundation level Mechanical Engineering Programme. The term 'integrated' refers to teaching and learning that is organised in a holistic manner that it brings together various aspects of different subjects or disciplines in a meaningful association and reflects real world situations (Shoemaker, 1989).

This thesis argues that the conceptual model of the Foundation programme under review was flawed in that the notion of using a metallurgical course, Engineering Materials and Science (EMS), as the centre-piece around which integration would take place, did not give sufficient natural affordance (Kress, 2000) for the integration of Mathematics into Science or Mechanics concepts. The lack of natural affordance, lack of validity and the existence of polarity (Jacobs, 1989) resulted in a 'fragmented' approach (Fogarty, 1991) in 2002. Continual re-evaluation of the course by the Foundation lecturers led to the evolution towards a de facto, new model, using Mechanics concepts as the centre-piece for integration for the programme. Mechanics has a high natural affordance with Mathematics as all of the concepts used are mathematically based. This led to a design that demonstrated more characteristics of a 'fully integrated approach' than of a 'fragmented' approach (Fogarty, 1991) by the end of 2005.

There were also a number of conceptual and design flaws that inhibited cognition of Mechanics concepts.

The theoretical predictions of the impact of an integrated curriculum model, is confirmed by this thesis.

1.2. Background and context

The Cape Peninsula University of Technology (CPUT) is the only one of its kind in a region that serves in excess of 4.5 million people (Statistics South Africa, 2004). In addition, the engineering field is an important player in the socio-economic development. There is a crucial shortage in skilled graduates in the Science, Engineering and Technology (SET) sector (Bloch, 2006). Under-preparedness in Mathematics for tertiary level study is a national and international phenomenon. There is thus a social interest in the evaluation of a Mathematics course that is part of a strategy towards addressing the shortage in engineering graduates. This evaluation of aspects of integration of the Foundation Mathematics course within the Department of Mechanical Engineering at CPUT, falls within the ambit of this social need.

1.3. Rationale

Twelve years into a democracy, South Africa still faces many developmental challenges. In Western Europe, North America and India the ratio of people to Engineers ranges from 130:1 to 450: 1, while in South Africa the ratio is 3200: 1 (South African Institution of Civil Engineers, 2006). There are also many unfilled vacancies for engineers, technologists and technicians. Only 5% of the students who write the Matriculation (school leaving) examinations attain high enough results to study science at tertiary level (HSRC, 2005). According to the Human Sciences Research Council (2005) the throughput rate for 'African' learners in Engineering is only 3% at universities in South Africa. Increasing the throughput of graduates and improving the quality of Science and Engineering programmes is one of the ways of meeting these developmental challenges. Since 2002 Universities of Technology in South Africa have introduced Foundational Programmes/provisions in their Science and Engineering programmes as a key mechanism for increasing throughput and enhancing quality (Jacobs & Jacobs, 2003). This is consistent with the National Education policy, which since 2005, has been funding these foundational provisions (Ministry of Education, 2005). This Case Study evaluates an aspect of a Foundational provision in Mechanical Engineering, with a view to contributing to its improvement.

1.4. The Research Problem

Fogarty (1991), Lake (2005) and many others have posited that an integrated curriculum enhances learning at a tertiary level of study. This Case Study evaluates aspects of the integration of Foundation Mathematics into Foundation Science within a Mechanical Engineering Diploma programme at a University of Technology, for the purpose of improving the programme. Both qualitative and quantitative methodologies were utilized in this Case Study.

1.5. Objectives of the study

Given the socio-economic need for greater numbers of engineering graduates, this study has the following objectives:

1. To contribute to a formative process of programme development and enhancement , and
2. To offer guidelines for improving the Mathematical component of the Foundational provision, within a Mechanical Engineering tertiary level of study.

1.6. Significance of this Research

The evaluation of Foundational provision within programmes is necessary if they are to meet their stated objectives. These objectives are spelt out in the Application by the CPUT for initial funding from the Department of Education:

The development of human resources is fundamental to socio-economic upliftment and meeting the challenges of our new democracy. The demand on higher education to enrol under-prepared students who meet the minimum requirements will remain a factor in the short to medium term. The key objectives for the development and provision of foundation projects and associated support systems are:

- To increase retention and throughput in identified programmes while ensuring quality
- To develop appropriate skills and experience for learners
- To develop a basic understanding of what an academic/professional career entails

- Orientation and preparing independent learners for Higher Education and Lifelong learning...(Peninsula Technikon, 2004)

1.7. Research Question formulation

In line with accepted practice for evaluation studies (Babbie & Mouton, 2001) this Case Study considers three key aspects:

Research Question 1:

How was integration of Foundation Mathematics into Foundation Science conceptualized and designed?

Research Question 2:

How was the integration of Foundation Mathematics into Foundation Science implemented?

Research Question 3:

What was the impact of the integration of Foundation Mathematics into Foundation Science?

1.8. List of abbreviations and terms

A number of abbreviations are used in the text. For ease of reference they are outlined together with some of the definitions used, on page xii, in the contents section of this thesis.

1.9. Framework of document

Chapter 2 discusses in detail the literature review on the subject. First it was necessary to describe the paradigm that provides the framework for the study. A broad summary is presented of typical problems that entry-level tertiary students face. This sets the scene for a brief international survey of factors that influence student learning of Mathematics at tertiary level, including within the field of technology. The South African context of Mathematics under-preparedness at tertiary level is thereafter briefly elaborated upon, providing an important backdrop for a description of Foundation programmes. This leads to a short discussion of the typical cognitive difficulties that entry-level tertiary students face. Some of the theories of

how students construct mathematical knowledge are then reviewed. This is necessary to provide a rigorous basis for evaluating strategies to enhance student learning in Mathematics. This leads directly to the discussion of the selected strategy that sets the framework for the addressing of the mathematical problems students face, namely an integrated approach to teaching and learning.

The Chapter ends with a summary of the main points of the literature review, their relevance in building a theoretical framework for the research findings and concluding remarks.

Chapter 3 outlines in detail the research methodology used in this study.

Chapter 4 outlines in detail the findings of the evaluation of the Concept and Design of the integration of Foundation Mathematics into Foundation Science.

Chapter 5 discusses the findings of the evaluation of the implementation of integration of Foundation Mathematics into Foundation Science.

Chapter 6 discusses the findings of the evaluation of the impact of the integration of Foundation Mathematics into Foundation Science.

Chapter 7, lastly presents a summary of the findings of this Case Study; it lists a number of recommendations for improvement of the Foundational Mathematical provision as well as outlining areas for future research.

CHAPTER 2

LITERATURE REVIEW

OF INTEGRATED CURRICULA FOR MATHEMATICS IN ENGINEERING

2.0. Introduction

In this chapter an overview is presented of the relevant literature that relates to specific aspects of the study. First a broad summary is presented of typical problems that entry-level tertiary students face. This sets the scene for a brief international survey of factors that influence student learning of Mathematics at tertiary level, including within the field of technology. The South African context of Mathematics under-preparedness at tertiary level is thereafter briefly elaborated upon, providing an important backdrop for a description of Foundation programmes. This leads to a short discussion of the typical cognitive difficulties that entry-level tertiary students face. Some of the theories of how students construct mathematical knowledge are then reviewed. This is necessary to provide a rigorous basis for evaluating strategies to enhance student learning in Mathematics. This leads directly to the discussion of the selected strategy that sets the framework for the addressing of the mathematical problems students face, namely an integrated approach to teaching and learning.

The Chapter ends with a summary of the main points of the literature review, their relevance in building a theoretical framework for the research findings and concluding remarks.

2.1. Factors that affect the performance of first year tertiary students

Problems of access and retention in the context of a need for mass education extending to tertiary level study are not new and have dated since the 1800's with the rise of modern industrial capitalism (Stahl, 2004). This study examines one of the strategies to enhance student learning, namely curriculum integration.

Before expanding on aspects of an integrated curriculum approach it is necessary to look broadly at the factors that influence the performance of first year tertiary students in general. This would sketch the context in which an integrated approach evolved as one of the strategies to enhance student cognition. Before looking at

curriculum integration it is also important to have a theoretical framework for explaining how students learn Mathematics.

The list below, of factors influencing the performance of first year students, is not comprehensive but indicates the complexity of developing strategies to attenuate or overcome factors that inhibit student learning, especially at entry level:

Affective factors:

1. Enhancing emotional development positively influences student cognition (Chickering & Reisser, 1993);
2. Personality integration, motivation, persistence and general wellbeing influence student learning (Shin & Kim, 1999);
3. Confidence, anxiety and self-belief influence the motivation of students (Braten & Olaussen, 2000);
4. Self-esteem, confidence and motivation of students are inter-related (Van Laar, 2000);
5. Family relationships (support) and wellness influence student academic performance (Yorke, 2000);

Social factors

1. A sense of belonging is necessary for successful academic outcomes (Bradley & Graham, 2000);
2. Recreational activities may contribute to successful academic outcomes (Belch *et al*, 2001);

Tertiary academic skills

1. Understanding and mastery of the values, attitudes and ways of thinking and doing within a particular discipline is a challenge (Amos, 1999);
2. Note-taking skills and effective learning and study skills for a tertiary environment of lectures, high class student numbers, high content and fast pace of lectures and tutorials (Woollacott & Henning, 2004);
3. Lack of academic literacy skills hampers progress of student cognition (Taraban *et al*, 2000);
4. Holistic programmes contribute positively to the development of generic skills and lifelong learning (Chickering & Reisser, 1993);
5. Peer tutoring, academic mentoring and faculty feedback all contribute positively to student success (Salem *et al*, 1997).

Level of cognitive development and support

1. Having the ability to conceptualise, generalise, for abstract thinking, of self-knowledge of cognitive strategies and the ability to critically evaluate them, to critically evaluate alternative solutions, is another challenge (Amos, 1999);
2. Learning styles and available academic support are factors that influence student cognition (Meyer & Shanahan, 2001);
3. There is an increasing spread in student abilities and in their preparedness of specific topics and techniques that are required for tertiary study (McInnes & James, 1995).

The above factors demonstrate that a multi-faceted approach is necessary to successfully address challenges that first-year tertiary students face. Strategies to enhance Mathematics cognition cannot operate in isolation from the above, more general factors.

2.2. Student under-preparedness in the Mathematics required for tertiary level study

2.2.1. The international context

In the context of 'globalisation' with its changing labour market, the importance of engineering graduate transferability of skills, lifelong learning and social competencies are heightened (Heitman, 2005). As problem solving and innovation are key features of engineering, it follows that the requisite mathematical competencies are evolving and are not static. The widening of access to tertiary level study in the 1980's and 1990's has brought with it greater problems with regard to mathematical preparedness (Parsons, 2003).

Student under-preparedness in Mathematics for tertiary level study is a global phenomenon and its existence is well documented (Schoenfeld, 1999; Taylor & Morgan, 1999; National Plan for Higher Education, 2001; Louw, 2002; Tertiary Education Strategy document, 2002; Heitman, 2005; Bloch, 2006). Students in the rest of Africa are no exception to under-preparedness in the Mathematics required for tertiary study in engineering (Kofoworola, 2004). He also writes on the need for a 're-engineering' of education in Mechanical Engineering in Nigeria to respond to global changes affecting the country. There is, however, a dearth in research on

Mathematics education (Schoenfeld, 1999), which places a limitation on this study on the one hand, but at the same time highlights its importance, on the other.

2.2.2. The South African context

Before discussing the difficulties that students face in under-preparedness for tertiary Mathematics it should be borne in mind that government policy on Academic Development (AD) also places a constraint on teaching and learning that may impact on its effectiveness (Jacobs & Jacobs, 2003).

One of these factors is a moderation in budgetary education expenditure that constrains tertiary level student numbers in 2006 to levels below that of 1996 (Ministerial statement, 2005).

The need to expand higher education is supported by studies on changes in market trends over the past 3 decades (Bloch, 2006 and HSRC, 2003). The public participation rate in Higher education has dropped from 17% in 1996 to 15% in 2000 (National Plan for Higher Education document, 2001a). Two main reasons are given for this: a drop in the numbers of school-leavers with a matriculation exemption (a requirement to enter university degree courses) and a fall in the retention rate. The fall in the retention rate has been ascribed to financial and academic exclusion (NAP, 2001a).

In particular, the NAP (2001a) notes that a significant constraint on increasing numbers in engineering is the small number of matriculants who have the required proficiency in Mathematics. They cite the cases of 1998 and 1999 when only 20 000 out of 550 000 school leavers obtained higher grade passes in Mathematics.

In South Africa there is the added burden of overcoming the heritage of a system that believed that people of colour were only good enough to be 'hewers of wood and drawers of water'. The DOE has as part of its priorities for producing the graduates required for social and economic development in South Africa, an increase in the participation rate in higher education; to increase the number of graduates; widening the social base of access and producing graduates with skills and competencies required to participate in the modern world in the 21st century (New Academic Policy planning framework-discussion document, 2001b). The Foundation Programmes are recognised as a key component of the DOE's stated objectives.

The DOE had limited access to Foundation programmes to students who do not meet the entry criteria but who show potential to graduate. This is a problematic formulation as it does not address the serious problem of under-prepared students who meet the minimum entry criteria and are at high risk of not completing the course, let alone the first year of study (Scott, 2001). The Foundation programme only addresses the problem indirectly by providing a steady stream of students for the first year intake. The experience of the former Technikon Pretoria's access programme, where students who meet the minimum entry criteria but who are under-prepared, and are given an option to join the Foundation programme, tends to support the argument for opening up access to mainstream students as well. The DOE has subsequently changed its position to allow students who meet the minimum entry requirements to be taken up in the Foundation Programmes from the start of 2007 (Ministry of Education, 2006). This poses design and implementation challenges for universities offering Foundational provision in the SET sector.

The introduction of Mathematical Literacy will not expand access in terms of the Science, Engineering and Technology (SET) sector as its planned articulation will be with work-related programmes and colleges (National Curriculum statement Mathematical Literacy, 2005), while the Mathematics subject is meant to articulate with the Higher Education Institutions (National Curriculum statement Mathematics, 2005).

The setting of new entry criteria for Diploma courses in Mechanical Engineering will be a challenge for Universities of Technology. The abolition of the Standard Grade levels, which currently are the entry level attainments of most students for the Diploma in Mechanical Engineering, also has implications for the type of problems that the Foundation Mathematics course in Mechanical Engineering at Universities of Technology will face (Both in terms of students numbers as well as curriculum issues). (The Foundation Programme, that forms the basis of this study, prepares students for the Diploma in Mechanical Engineering).

2.2.3. What are Foundation programmes?

Foundation programmes are part of Academic Development at tertiary institutions in South Africa. The main aim of an AD programme is to provide additional support to enable students to develop their subject knowledge, academic literacies and skills to a level that provides an effective foundation for successfully completing their HE (Higher Education) studies (Scott, 2001). This carries with it substantial curriculum

redesign. In the SET sector, which engineering locates itself the form of AD provision is with Foundation programmes or bridging courses, normally of length of one or two semesters. Where the programme design ensures that the additional elements articulate successfully with the standard tertiary curriculum, the product can be termed an extended curriculum. Foundation programmes should be forward looking (vertically integrated).

Irrespective of the form that AD takes, the extended curriculum incorporate substantial additional provision, that is planned and scheduled coursework, over and above what is prescribed for the standard university programme, with a workload usually equivalent to one or two semesters of full-time study (Scott, 2001).

There are 4 broad categories of academic support provision occurring at tertiary educational institutions in South Africa:

1. Concurrent supplementary tuition
2. Non-standard courses or modules
3. Reduced curriculum or slow stream models
4. Integrating AD into the curriculum (Scott, 2001)

The extended curriculum model of AD is the one that has been adopted by the institution whose Foundation programme in Mechanical Engineering and its Mathematics course is the subject of this evaluation study (Jacobs & Jacobs, 2003). It is necessary now to examine the difficulties that students face in general at first year tertiary level study before exploring the subject more deeply.

2.3. What are the cognitive difficulties that characterise student under-preparedness for tertiary mathematics?

There is unevenness among student Mathematical conceptual and content knowledge and it is difficult to generalise as each new group of entry level students at tertiary institutions have varying knowledge, styles and approaches. Students often either have forgotten or have misconceptions of basic topics such as estimation, algebra, graphing, manipulation of exponents (Taylor & Morgan, 1999); students tend to concentrate on the specific details of individual graphs rather than on general properties (Galbraith & Haines, 2000). Students often have a number of difficulties with calculus (Schoenfeld, 1999). These are just some of the cognitive difficulties that

students have. It is not the intention of this study to compile a comprehensive list of all possible problems that students have (as this is virtually impossible) but to evaluate a programme that attempts to address these.

The reasons for poor performance of students in Mathematics go beyond a mere lack of content knowledge and include lack of awareness of their own learning (Schoenfeld, 1999).

Often students, even though they may know the right methods, would not be able to solve mathematical problems because of 'poor metacognitive strategies' which has them going off on 'mathematical wild goose chases' (Shoenfeld, 1999: 3). 'Student metacognition' can be described as their awareness, control and knowledge of their own learning (Baird, 1990).

Many students may be able to recall large quantities of information, including the field-specific terminology, they may even pass examinations, but they are unable to show understanding of what they have learnt (Smith *et al*, 1999). Students with a weaker conceptual understanding of Mathematics often misinterpret topics as a loose collection of unconnected rules (Tall & Razali, 1993). An underlying feature of studies into student mathematical cognition point to the far-reaching negative implications of fragmented student learning approaches and the apparent absence of learning strategies to effectively build a bridge from procedural knowledge to conceptual understanding (Galbraith & Haines, 2000).

However, the design and implementation of tertiary courses in engineering could also contribute to hindering the development of student conceptual understanding by focusing on a procedural approach (Case & Marshall, 2004). This is supported by studies which show that students adopt an algorithmic approach for solving textbook problems but do not develop conceptual understanding (Clement *et al*, 1980); students adapt their learning approaches to reproducing content and techniques for examination purposes (Galbraith, 1984); students tend to forget the essence of the topic after examinations rather than retain and build conceptual mathematical knowledge structure (Anderson *et al*, 1998). The replacement of examinations with in-depth assessment (when details of analyses, explanations and presentation of solutions are taken into account) should be considered as they give a better indication of student conceptual understanding (Sazhin, 1999).

There is contradictory evidence on the extent of the under-preparedness of students for tertiary level Mathematics. Parsons (2003) claims that the standard of student mathematics cognition has declined over the past few years; while Taylor and Morgan (1999) claim that the standard has not dropped but has remained consistently low. The point is established, however, that widespread student under-preparedness for tertiary study in Mathematics persists.

Mathematical misconceptions are part of the cognitive framework that students arrive with when they enter tertiary study and are also an important factor to bear in mind when conceptualising and designing courses (Galbraith & Haines, 2000).

The above studies lead to the necessity to explore possible explanations of student mathematical cognition. This would provide a basis for the explanation of the obstacles to learning. It is also imperative to interrogate the teaching and learning strategy adopted to promote student conceptual development. A theoretical framework would then be established for this evaluation study. The exploration of student mathematical cognition is dealt with first. This is followed by an exploration of an integrated curriculum approach.

2.4. Theories of how students construct Mathematical knowledge

Research into the way students handle reading tasks has led to the discovery of different learning approaches (Marton & Säljö, 1976a, b). Two broad categories emerged from the study, namely the existence of a deep approach and a surface approach. Typically, students who used a deep approach aimed to understand underlying meanings in the presented text; while those who used a surface approach focused on the elements of the text in an unconnected fashion and tried to memorise as much as possible. The meaning of the term 'approach to learning' was later expanded to incorporate the strategy students used (what they do) with their intention (why they do it) to describe their thought processing activities when tackling reading tasks (Marton & Säljö, 1984).

2.4.1. 'Learning approaches' versus 'Learning styles'

It is important to clarify that the learning approach a student may use cannot be generalised to be seen as a characteristic of him/her. A learning approach is context-

bound as a student may use a surface approach in one situation but use a deep approach in another (Marshall & Case, 2005).

The pedagogical challenge in this regard would be to design teaching to elicit a deep approach to learning (Linder & Marshall, 1997).

'Learning styles' describe characteristics of learning that remain fairly stable across different contexts (Case & Fraser, 2002). Learning styles include characteristics of learning more through visual as opposed to verbal inputs and vice versa; deductive as opposed to inductive styles; global as opposed to sequential.

The pedagogical challenge in this case leads to teaching methods that accommodate the diversity of learning styles in the classroom (Felder, 1996).

Theories of learning approaches and learning styles are complementary (Case & Fraser, 2002) but are based on different theoretical assumptions (Marshall & Case, 2005).

This study is specifically located in the context of Mathematics education. Thus it is appropriate to explore theories of approaches to learning Mathematics. What is of particular importance in this is a description of a mathematical equivalent of deep and surface approaches and a framework for explaining transitions from 'surface' to 'deep'.

2.4.2. Process/object duality

Concepts in Mathematics have a duality in that they may be conceived of as being a process (operational) and an object (structural) at the same time (Sfard, 1991).

The mathematical symbol that represents objects being either process or object (concept), may also be called a procept (Gray & Tall, 1994). For example, the number 8 may be seen as an object itself, 8, or as the end-product of the process of addition, $1 + 7$, or $2 + 6$. This approach of seeing 8 both as a number (object) and as the end product of a process of addition, may then be called a proceptual approach (Gray *et al*, 1999). Some students may be unable to see $1+7$ as equivalent to 8 without the use of the equality symbol, demonstrating that they are focusing on the process of addition, on the detail, at the exclusion of the end object that it also represents (Sfard & Linchevski, 1994).

The inability of students to adopt a learning approach which sees 'object' – 'process' equivalence is called the 'conceptual gap' (Sfard & Linchevski, 1994) or the 'proceptual divide' (Gray & Tall, 1994). It is important to re-emphasise that these terms refer to learning approaches and not learning styles.

This concentration on objects or on processes as separate entities, on the one hand as opposed to concentrating on objects and/or actions/processes and their interconnection on the other, has been identified as one of the major problems in learning Mathematics (Cobb, Yackel & Wood, 1992).

2.4.3 The theory of reification

Sfard and Linchevski's (1994) theory of reification posits the existence of three stages in the formation of a mathematical concept: (a) interiorisation; (b) condensation; and (c) reification.

Interiorisation is described as the stage where a student performs operations (processes) on lower level mathematical objects. As the student becomes more familiar with performing the processes, s/he can think about what would happen without actually carrying it out. At this stage interiorisation is said to have occurred. For example, the multiplication of natural numbers with one another is said to be interiorised when the student no longer has to go through the process of repeated addition but remembers the process of multiplication. The concept of multiplication is then said to be interiorised.

Condensation is described as a stage when a complicated process is condensed into a form that makes it easier to use and think about. An example may be the use of the definition of a derivative from its mathematical first principles. This is the stage where a new concept is 'born' (Sfard, 1991:19) but the new concept remains tied to an algorithmic process. The student shows an increasing ability to alternate between the different representations of a concept.

Reification is described as a stage where the student can conceive of the new mathematical concept as a complete object with characteristics of its own. While the interiorisation and condensation processes occur gradually, reification usually occurs as a sudden shift (Sfard, 1991). For the stage of reification to occur, it is a

prerequisite that the 'new' concept is used, in other words is seen as part of a higher level process (Goodsen-Espy, 1998). In other words, reification only occurs if the student uses a proceptual approach.

A diagrammatic representation of reification may be given as follows:

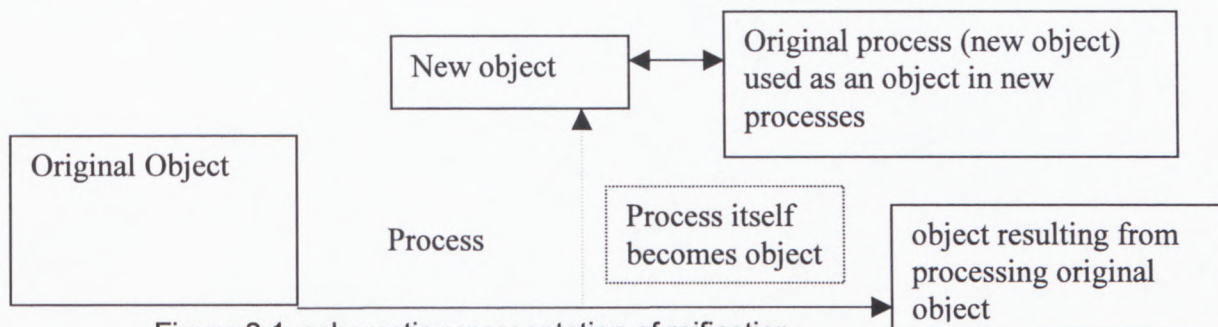


Figure 2.1. schematic representation of reification.

By careful design, an integrated approach to teaching and learning could be able to demonstrate the process or from its criteria or characteristics, be able to demonstrate the original object as a special case of the new object (process reified into new object). In some cases the original object may be able to be deduced from the new object. A key challenge would be to set a framework that encourages a transition of a process into a new object.

2.4.4 Reification and a MATH Taxonomy

The stages of interiorisation, condensation and reification correspond to the respective Group A, B and C thinking skills outlined Table 2.1. Smith, Wood, Coupland, Crawford, and Ball (1996) proposed a MATH Taxonomy (Mathematical Assessment Task Hierachy) to assist in the designing of assessments which could aid undergraduate Mathematics students with their metacognitive development. The taxonomy was based on the thinking skills required to complete certain tasks rather than being a reflection of the level of difficulty. Group A thinking skills are associated with a surface learning approach while Group C thinking skills are associated with a deep learning approach. Group B was defined as somewhere between deep and surface approaches (Table 2.1).

Table 2.1 MATH Taxonomy (adapted from Smith *et al*, 1996: 67)

Group A (interiorisation)	Group B (condensation)	Group C (reification)
Factual knowledge	Information transfer	Justifying and interpreting
Comprehension	Application in new situations	Implications, conjectures and comparisons
Routine use of procedures		Evaluation

The MATH taxonomy has a major limitation in that it is constructed around examinations. In realizing that assessments shape how students learn, the Taxonomy ignores the intention of students in learning the required skills. 'Information transfer' includes for example, recognizing the applicability or otherwise of a formula or method in a particular context, while 'application in new situations' (both are Group B skills) include choosing and applying appropriate algorithms (Smith *et al*, 1996). If the aim of the student learning of these skills was to pass the test or examination, then this demonstrated an 'algorithmic' or a procedural surface approach, while if the student aim was to gain understanding, then a procedural deep approach is being demonstrated (Case & Marshall, 2004). The surface procedural approach would lead to a lesser metacognitive development, while the procedural deep approach would lead to a greater metacognitive development. As the promotion of procedural deep approaches could hinder a conceptual deep approach (Case & Marshall, 2004), it is not a matter of merely identifying different thinking skills that occur in assessments but of developing strategies to promote conceptual deep or proceptual or Group C thinking skills/approaches.

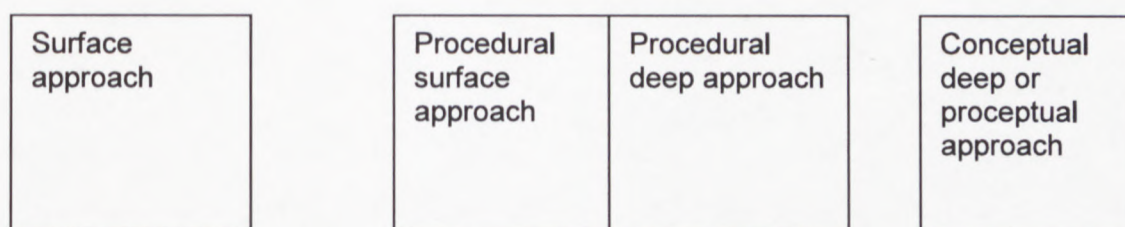


Figure 2.1 Approaches to learning, adapted from Case & Marshall (2004:61)

Although Bloom's Taxonomy is widely regarded as being out of date (Ernest, 1999), the development of a MATH Taxonomy (Smith *et al*, 1996) based on the hierarchy of tasks is still of some relevance. 'Analysis' and 'synthesis' would correspond to the

Group C skills referred to in Table 2.1 above. These mental activities would assist in the unpacking and repacking (reconceptualisation) of the underlying schemata faced in various situations.

(Intuition is based on schemata. A schema is a cognitive structure which has reference to a group of similar action sequences; these sequences are strong bounded totalities in which the constituent behavioural elements are firmly interrelated (Fischbein, 1999).)

2.4.5. Theories of the transition from surface to deep learning approaches

The theory of reflective abstraction (Piaget, 1985) has been extended into 4 categories by Cifarelli (1988), as a mechanism to attempt to explain how students develop conceptual knowledge. This describes the changes students undergo while attempting a problem (generally over a shorter period) while the theory of reification offers an explanation of student cognition of a mathematical concept, generally over a longer period (Goodsen-Espy, 1998).

The first level is Recognition, described as an approach of a student being able to recognise characteristics of a previously solved problem in a new situation but not being able to anticipate possible difficulties that may arise and would not be able to mentally run through a solution to confirm or reject it. This may be seen as equivalent to a procedural deep approach (Case & Marshall, 2004). The procedural deep approach was described by Case and Marshall (2004) as a strategy of relating formulae to each other or parts of algorithms to other parts, with the aim of through application gaining some future understanding.

The second level of reflective abstraction is Re-presentation, described as an approach where a student is able to run through a solution mentally and anticipate sources of difficulty; are able to recognise similarities but could not take the results as a given and would be unable to think about potential (new) methods of solutions nor the results of such methods. This may be seen as a procedural deep approach (Case & Marshall, 2004) but with more experience.

The third level is Structural Abstraction, described as an approach when a potential solution is evaluated based on mental run-throughs of possible (new) methods as well as previously used methods; characteristics are identified that are necessary to

solve the problem and the merits of the solution may be evaluated based on these characteristics.

The fourth level is Structural Awareness, described as an approach where a student does not have to run through the solution activity but can anticipate the results. The problem structure has become an object of reflection.

There is increasing flexibility of thought in terms of the solution from level one to level four.

Reflective abstraction may be used to assist in assessing the degree of concept formation that a student has attained (Goodsen-Espy, 1998). Students who operated at the first two levels of reflective abstraction had weak conceptions of variables and equality; they did not use equality statements or used equality symbols not to indicate equivalence but only for arithmetic statements. For students to make a successful transition from Arithmetic to Algebra students needed to use approaches beyond the first two levels, namely to have the approaches of either Structural Abstraction or Structural Awareness. The third and fourth levels were characterised by consciousness of learning, that is, metacognitive development. Crucial here was student reflection on new processes or possible new solutions, which is consistent with the theoretical description of lower level reification only occurring through higher level interiorisation (Sfard, 1991). Charts helped students make the transition from Arithmetic to Algebra which indicates that a representation of a suitable equivalent form may aid students develop from using a surface approach to using a deep approach (Schoenfeld, 1994; Goodsen-Espy, 1998). What was crucial was that the introduction of charts had to be linked to student reflection back onto their own activity. The examples used to aid the development of student learning, such as charts, should be equivalent to the concept being developed as the incorrect selection of examples could hinder conceptual development (Davis *et al*, s.a.; Galbraith & Haines, 1999). This is supported by findings that student conception of equality precedes the conception of inequality (Sfard & Linchevski, 1994; Goodsen-Espy, 1998).

Students often do not abandon incorrect conceptual views without a measure of cognitive conflict (Hubbard, 1997). This conflict could typically include strengthening of conceptual networks by asking questions requiring students to reflect on results, to make comparisons, to reverse their thinking, to observe patterns, to relate new

procedures and results back to previous knowledge. Crucially linked to enabling students to gain conceptual knowledge or to reconceptualise their notions was the strategy which challenges isolated knowledge and which locates mathematical concepts or procedures within a network of knowledge(Sfard & Linchevski, 1994) . This leads directly to a discussion of an integrated curriculum approach.

The challenge of Engineering Mathematics offers possibilities for the use of integrated teaching and learning methods due to the nature of the discipline, namely setting out to solve real-world problems, that is providing a setting of a multitude of equivalent forms of concepts and of offering opportunities for lower level reification of concepts through settings of higher level interiorisation (use of the concepts in higher level settings), (Sfard, 1991).

2.4.6. On Fallibilism

There is a growing perspective of fallibilism in mathematics (Ernest, 1999). Mathematics in Engineering is evolving and is influenced by globalisation (Heitman, 2005; Kofoworola, 2004). This has implications for proofs no longer being seen as absolutes but having validity only from its context. A Fallibilist perspective implies tacit and propositional knowledge needing human understanding, activity and experience to make or justify Mathematics. From this one may deduce that Mathematics is part of social activity and is thus subject to its laws of motion, including its relevance within a paradigm that itself is in motion. Experience in past problems leads to an expanded knowledge base that underlies success in problem solving (Schoenfeld, 1985 & 1992). The very process of problem solving is a driving force towards the development of a global understanding of concepts/processes being studied. As Mathematics from a fallibilist perspective takes its validity from its context, integrated teaching and learning from this perspective is implied.

Having interrogated some of the theories of student learning of tertiary mathematics it is appropriate to review the theoretical basis of one of the teaching and learning strategies to enhance student cognition, namely an integrated curriculum.

2.5. The integrated curriculum

There is widespread support for the use of curriculum integration as a means to enhance student learning at entry level within tertiary level study, including the field of

engineering (Jacobs & Jacobs, 2003; Davies *et al*, 2004; Gerrard *et al*, 2004; Goodwin & Forsyth, 2004). This view is shared by Technology students in tertiary institutions (Coniavitis *et al*, 2005).

An integrated curriculum may be described as 'interdisciplinary teaching, thematic teaching, synergistic teaching' (Lake, 1994:1). There are several different ways of integrating programmes. It is useful to categorise them as this could assist with a process of design as well as providing a guide to evaluation of an integrated curriculum. After exploring a description of different levels of integration it is necessary to discuss the theoretical underpinnings of an integrated curriculum strategy.

2.5.1 A model of levels of integration

Ten levels of curriculum integration have been described (Fogarty, 1991), each with their distinct advantages and disadvantages, from distinct separation to full integration (see Table 2.2 below)

Table 2.2 Levels of curricular integration (adapted from Fogarty, 1991)

Name	Description	Advantages	Disadvantages
Fragmented	Separate and distinct disciplines	Clear and discrete view of a discipline	Connections are not made clear for students; less transfer of learning
Connected	Topics within a discipline are connected	Key concepts are connected, leading to the review, reconceptualization and assimilation of ideas within a discipline	Disciplines are not related; content focus remains within the discipline
Nested	Social, thinking, and content skills are targeted within a subject area	Gives attention to several areas at once, leading to enriched and enhanced learning	Students may be confused and lose sight of the main concepts of the activity or lesson

Sequenced	Similar ideas are taught in concert, although subjects are separate	Facilitates transfer of learning across content areas	Requires ongoing collaboration and flexibility, as teachers have less autonomy in sequencing curricula
Shared	Team planning and/or teaching that involves two disciplines focuses on shared concepts, skills or attitudes	Shared instructional experience; with two teachers on a team it is less difficult to collaborate	Requires time, flexibility, commitment and compromise
Webbed	Thematic teaching, using a theme as a base for instruction in many disciplines	Motivating for students, helps students see connections between ideas	Theme must be carefully and thoughtfully selected to be meaningful, with relevant and rigorous content
Threaded	Thinking skills, social skills, multiple intelligences, and study skills are "threaded" throughout the disciplines	Students learn how they are learning, facilitating future transfer of learning	Disciplines remain separate
Fully integrated	Principles that overlap multiple disciplines are examined for common skills, concepts, and attitudes	Encourages students to see interconnectedness and interrelationships among disciplines, students are	Requires interdepartmental teams with common planning and teaching time

		motivated as they see these connections	
Immersed	Learner integrates by viewing all learning through the perspective of one area of interest	Integration takes place within the learner	May narrow the focus of the learner
Networked	Learner directs the integration process through selection of a network of experts and resources	Pro-active, with learner stimulated by new information, skills or concepts	Learner can be spread too thin, efforts become ineffective

The ten levels described in Table 2.2 (Fogarty, 1991) is consistent with a description of the extremes of integration being categorised as weak (fragmented) or strong (fully integrated) as set out in Table 2.3 (Boughey, 2002).

Table 2.3 Characteristics of an integrated curriculum (Adapted from Boughey, 2002)

<p>•WEAK</p> <ol style="list-style-type: none"> 1. Subject specific 2. Subject as vehicle for teaching 3. Teaching and assessment separated 4. Separate subject outcomes 5. Separate fundamental modules 	<p>•STRONG</p> <ol style="list-style-type: none"> 1. Theme/Case Study 2. Disciplinary perspective on theme/Case Study 3. Team teaching and joint assessment 4. One set of outcomes 5. Fundamentals integrated completely
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2.5.2. Bridging versus Foundation programmes

Myburgh (2002) looks at the thinking skills required for the passing of a Higher Grade matriculation examination. This is used as a base line from which to analyse the University of the Western Cape (UWC) Pre-calculus course. Whereas this is a useful exercise in uncovering basic skills, the thesis falls short in that it is 'backward looking'

rather than forward looking, and critiques rather within the framework of a bridging course rather than a Foundation course. A weakness is that the mathematical skills necessary for success within relevant UWC courses, is not directly examined. By considering the Pre-Calculus course as a stand-alone model runs the risk of the disadvantages of a fragmented model, namely that Mathematical conceptual development of the students may be weak and by having an examinations focus, students may adopt procedural approaches or have it reinforced (Case & Marshall, 2004).

Boughey (2002) outlines the essential differences in the following Table:

Table 2.3 Comparison between Bridging and Foundation programmes (adapted from Boughey, 2002)

BRIDGING	FOUNDATION
1.Backward looking	1.Forward looking
2.Fills gaps in matric syllabus	2.Prepare foundation for tertiary study
3.Background knowledge	3.Unpacking essentials of courses to follow
4.Relies on teacher expertise	4.Taught by mainstream staff

A focus on the matric syllabus inherent in bridging courses may inhibit mathematical conceptual development in that a crucial element of the use of concepts at a higher level may be absent, limiting opportunities for reification (Sfard, 1991). Foundation courses (Boughey, 2002) would, on the other hand, promote mathematical conceptual development through opportunities for reflection at higher levels.

The question is not straightforward as some students may have so many conceptual gaps or misconceptions that matric mathematics may provide them with higher level opportunities of reflection necessary for reification of concepts (Sfard, 1991).

(By vertical integration is meant integration with subject matter from higher levels within the same programme; by horizontal integration is meant integration with subject matter of courses on the same level as the subject under question.)

2.5.3. Discussion of the levels of integration

Set out below is a brief examination of the ten levels of integration (Table 2.2) from the theoretical perspective of cognitive development as established above:

The Fragmented approach where there is separate and distinct disciplines limits the opportunities for 'equivalence' (Goodsen-Espy, 1998) as subject matter is not linked. Concept formation is limited in that concepts are seen only as objects in their respective subjects/disciplines and not as having equivalent forms in other disciplines, weakening conceptual development (Gray & Tall, 1994) as they are not seen as part of processes in other disciplines. Procedural approaches tend to result from weak conceptual development, consistent with the prediction of less transfer of learning (Table 2.2).

The Connected approach is where concept formation within a discipline is promoted as there is opportunity for concepts to be used at higher levels (Sfard, 1991). Learning of concepts that occur in multiple disciplines are not supported, thus limiting the scope of the cognition. This is consistent with development of cognition within the discipline only (Table 2.2).

The Nested approach deals with social and thinking skills needed within a subject area, thus appears to be based more on deconstructing rather than on offering opportunities for learning at higher levels, a process needed for mathematical concepts to be developed (Sfard, 1991). This is consistent with the predicted disadvantage of possible confusion (Table 2.2).

The Sequenced approach would have some benefit to the student as similar ideas would be co-ordinated although the subjects are still separate. The student could make the connection, on their own, of equivalence (Goodsen-Espy, 1998) across subjects, which would enhance learning. This is still limited as the opportunity for learning at higher levels across disciplines needed for some conceptual development, although possible, may be limited. Structurally, this method opens itself to students adapting their learning approaches to a procedural deep approach in the still separate disciplines, due to the way assessments are designed (Case & Marshall, 2004).

The Shared approach would promote conceptual development as the focus is on sharing of concepts (equivalence), and opportunities would be presented of using

concepts at higher levels in equivalent forms. The limitation would be that only 2 subjects are involved in the concept formation while it may have relevance in other subject areas.

The Webbed approach has the advantage that the concepts that are used in the chosen theme would be supported but it would be very difficult to find themes that support all concepts. Some concepts would find equivalent forms and be supported while others would not necessarily be so.

The Threaded approach has metacognitive skills built into its approach which should enhance concept formation within the subject area. It may be seen as a higher form of connected integration with enhanced results.

The Fully Integrated approach would allow for maximum conceptual development as all opportunities for equivalence is part of its focus. Opportunities for using concepts at higher levels in equivalent forms are many, with the most conceptual development taking place in this approach. This would have to be combined with metacognitive skills development as the mere existence of equivalence in multiple situations does not guarantee that students will abandon misconceptions or develop new conceptions (Hubbard, 1997).

The Immersed approach leads to narrow focus as students develop conceptual understanding within the field they find themselves in and do not see the connection to other fields where similar concepts are equivalent (Goodsen-Espy, 1998).

A Networked approach where the student directs the integration process may have the disadvantage of dealing with too many concepts at the same time. Concept formation takes time (Sfard & Linchevski, 1994) and the exposure to too many at the same time may weaken the concept formation of them all.

This leads directly to an interrogation of the theoretical basis of an integrated curriculum strategy.

2.5.4. The theoretical basis of an integrated curriculum strategy

An integrated curriculum provides opportunities for learning experiences that could develop skills and knowledge, while contributing to an understanding of conceptual

relationships (Lake, 1994). This is consistent with current research into academic literacy, which challenges the 'autonomous' (Street, 1984) or decontextualised skills-based model of literacy. Theorists such as Street (1984) and Gee (1990) propose an 'ideological' (Street, 1984) or 'social' model of literacy. Literacies are discourses which are historically and socially defined (Gee, 1990). There are primary discourses and secondary (engineering, academic) discourses and the primary discourse could present a framework for the acquisition of secondary discourses (Gee, 1990). Secondary discourses are acquired by student exposure to models in meaningful and functional settings rather than through explicit teaching (Gee, 1991). Thus the notion of multiple literacies exists – with each disciplinary and work domain having its own literacy practices. Academic literacy could now more clearly identified as 'academic literacy for mechanical engineering' - and is seen as a set of socio-cultural practices embedded in the contexts of mechanical engineering as a discipline. However, real-world problem solving is unlikely to be part of the curriculum (Jurdak, 2006). Full integration with respect to contextual problem-solving has to balance the authenticity of the problem with the mathematical requirements of the curriculum. This does not negate the finding that learning occurs faster and more in depth when presented in meaningful contexts (Lake, 1994; Bot *et al*, 2005).

2.5.5. Discussion of 'academic literacy for mechanical engineering'

The factors mentioned below are not meant to be comprehensive but illustrate the complexity of the challenges facing course designers of an integrated curriculum:

Integration does not have to be an all or nothing approach, should be carefully implemented and courses to be integrated have to have some form of affinity or 'natural affordance' (Kress, 2000). The tasks themes and projects must have validity within each discipline, for each discipline and beyond the discipline (Jacobs, 1989). In other words the integration should not be artificially forced. Some aspects of integration may be usefully run 'in parallel' while others may be more usefully integrated (Fogarty, 1991).

'Natural affordance' and validity within and beyond each discipline is another form of the 'equivalence' (Goodsen-Espy, 1998) that is required for conceptual development as well as offering opportunities for use of concepts at higher levels in the same or equivalent settings. Through the use of Group C thinking skills (Smith *et al*, 1996), sensitivity to different approaches to learning as well as descriptions of ways in which

reification of concepts take place (Cifarelli, 1988; Sfard , 1991; Gray & Tall, 1994; Sfard & Linchevski, 1994; Case & Marshall, 2004) the theories of academic literacy (Street, 1984; Gee, 1990 & 1991) are enriched. Both 'streams' of thought should be combined (Marshall & Case, 2005) when considering the implications for the conception and design of an integrated curriculum involving engineering mathematics.

The question of 'polarity', where some disciplines consider some aspects less or more important than others, need to also be taken into account (Jacobs, 1989). This points to a lack of conceptual 'equivalence' as the same nominal term may have different conceptual understandings in different disciplines.

The different world views of different lecturers may also be a concern, eg where one holds a constructivist world view while others may hold to a transmission world view (Jacobs, Winberg, Wright & Wyrley-Birch, 2002). This refers to lecturers holding different conceptual views on terms that may be presented in multiple subjects.

The conceptual and practical constraints placed by the broader field of engineering , industry, Department of Education (DOE), the engineering faculty and the Mechanical engineering department needs to be examined.

Constructive alignment (Coleman, 2004) is not sufficient to ensure conceptual development but factors such as cognitive conflict, equivalence, should also be considered in design of programmes.

Before summarising the implications for an integrated curriculum involving engineering mathematics, it is important to dwell on the impact of curriculum integration.

2.5.6. The impact of a curriculum integration strategy

In addition to the advantages and disadvantages of the different levels of integration (Fogarty, 1991) the following are also reported as possible consequences of an integrated curriculum:

- Integrated curriculum helps students apply skills
- Integrated knowledge base leads to faster retrieval of information

- Multiple perspectives lead to a more integrated knowledge base
- Integrated curriculum encourages depth and breadth of learning
- Integrated curriculum promotes positive attitudes in students
- Integrated curriculum provides for more quality time for curriculum exploration (Lake, 1994).

Further, an integrated approach to teaching and learning is needed to encourage students to see more clearly the essence, the details of the subject being studied as well as interconnections between concepts (Reid & Petocz, 2004).

Higher levels of curriculum integration are also linked with higher likelihood of improved student outcomes (Arendale, 2004).

When group work is used in an integrated teaching and learning approach, it has the following impact:

1. promoting cognitive elaboration
2. enhancing critical thinking
3. providing feedback
4. promoting social and emotional development
5. appreciating diversity, and
6. reducing student attrition (Smith, K A., Sheppard, SD., Johnson, DW. & Johnson, RT. 2005).

Group work and a problem-centred approach assist tertiary Mathematics learning and enhances student confidence in problem solving (Middleton & Spanias, 1999).

Although a course may be conceptualized and designed to achieve metacognitive development, it does not follow that such development will be achieved (Case & Fraser, 2002). Achieving a high level of curriculum integration is a complex task and faces many challenges.

2.6. Summary of the implications for the conception and design of an integrated curriculum mathematics course

This study brings together the notion of academic literacy and approaches to learning as complementary theories to provide a framework for evaluation. Factors that should be considered when setting up and implementing an integrated curriculum Mathematics course include:

First year challenges

These include taking into account general factors that affect first year students at tertiary level such as in section 2.1 above such as affective/emotional issues, social integration, tertiary academic readiness, student cognitive levels and support mechanisms required.

Considerations from academic literacy theory

- The subject matter to be integrated should have some affinity and 'natural affordance' (Kress, 2000);
- The subject matter to be integrated should have validity within each discipline, for each discipline and beyond them (Jacobs, 1989). The concepts to be integrated across disciplines should be equivalent forms (Goodsen-Espy, 1998);
- Integration should not be forced and where it is not possible then concepts should be developed/taught in parallel (Fogarty, 1991);
- Polarity of concepts, with different meanings in different disciplines should be considered (Jacobs, 1989);

Factors relating to formative assessment

- Use should be made of cognitive conflict (Hubbard, 1998) when promoting Group C (Smith *et al*, 1996) thinking skills (in the appropriate settings);
- Constructive alignment (Coleman, 2004) should be considered in conjunction with other factors like cognitive conflict (Hubbard, 1997) and not in isolation;
- The use of examinations may encourage procedural approaches and hinder conceptual approaches (Case & Marshall, 2004). The replacement of examinations with in-depth assessment should be considered (Sazhin, 1999);

Staffing requirements

- It is best designed and delivered by academic staff with sound knowledge of and interest in relevant educational theory and practice, as well as sufficient expertise in the field in the subject matter (Scott, 2001);

Broader context of Mathematics

- Mathematics itself operates in the context of global factors and is evolving (Ernest, 1999);

The process of concept formation (from learning approach theory)

- Concept formation goes through stages and takes an extended time (Sfard & Linchevski, 1994);
- Internal reflection of concepts in equivalent settings (Goodsen-Espy, 1998) or forms (process and object) , as a procept, aids concept formation (Sfard, 1991; Gray & Tall, 1994); in other words opportunities should be sought for proceptual (Gray & Tall, 1994) triggers/cues (Galbraith & Haines, 1999);
- Reification of concepts requires its use at a higher level and reflection on this process (Sfard, 1991);
- Structural awareness and Structural abstraction are crucial to concept formation and require reflection (Cifarelli, 1988).

2.7. Conclusion

Under-preparedness in Mathematics among tertiary entry-level students is an international phenomenon. This also applies to the Engineering sector. How students construct Mathematical knowledge and their approaches to learning are important elements that need to be borne in mind when developing strategies to aid their metacognitive development. An integrated approach to curriculum conception, design and implementation is a widely accepted strategy in South Africa and internationally. There are a number of factors to bear in mind when setting up and implementing an integrated curriculum. This is by no means a simple task but a complex one. The factors listed in summary in 2.6 provide a theoretical framework for this Evaluation Study.

The methodology employed when evaluating curriculum integration of the Foundation Mathematics course, needs to be able to effectively shed light on the relevant aspects to enable suggestions to be raised to improve the course and the programme itself. This leads directly to the next Chapter which deals with the methodology used in this Study.

CHAPTER 3

RESEARCH METHODOLOGY FOR AN EVALUATION CASE STUDY ON AN INTEGRATED CURRICULUM

3.0 Introduction

This Chapter starts off by elaborating on the reasons why a Case Study approach was adopted. It then examines the differences between research and evaluation. The theoretical framework for the study is set by substantiation on the selection of an interpretivist paradigm. The scope of the evaluation is outlined with the generation of appropriate evaluation questions on conceptualisation; design; implementation and impact of the Foundation Mathematics course (see Table 3.1). The actual methodology used is then explained in detail. The areas elaborated on are: the timing and timeframe for the Study; the use of qualitative data; triangulation; standardization of data collecting procedures; the analytical method used with respect to each of the research questions on conceptualisation, design, implementation and impact of the Foundation Mathematics course. Ethical considerations that were taken into account in the Study are discussed and the Chapter ends with brief concluding remarks.

3.1. Why a Case Study approach

This research takes the form of a Case Study of an Engineering Foundation Programme at a University of Technology, with the focus on evaluating the integration of Mathematics into a Mechanics-based subject (Foundation Science). The purpose of the evaluation is to provide formative feedback to the Faculty in which the study locates itself. A Case Study approach is relevant when a rich, detailed description in its real-life is useful and too complex for survey or experimental strategies (Guba & Lincoln, 1989). Case studies lend themselves to exploration of the whole situation within its context as perceived and understood by their participants (Adelman, Kemmis, & Jenkins, 1980). This type of study is particularly appropriate when the researcher is integrally involved in the case (Hitchcock & Hughes, 1995). The researcher is the facilitator/lecturer of the Foundation Mathematics course that is the subject of this study. This means,

however, that great care had to be taken to triangulate findings (see section 3.6.3 below).

In its evaluative use, Case Studies may be strongly linked to formative feedback to initiatives or interventions (Stenhouse, 1985). Interim findings of this study were presented for comment and discussion to the Foundation lecturing staff as well as the broader staff of the Department of Mechanical Engineering at CPUT (Bellville campus). Upon completion of this work the findings will be presented to this Department as part of ongoing initiatives to improve teaching and learning.

Case Studies have come under criticism from a positivist perspective due to the difficulties in external validity, such as having its findings replicated (Smith, 1991). This does not negate the use of case studies, as reality is more complex and subtle than a laboratory experiment. What is highlighted by the positivist critique is the need for Case Studies to be placed on a rigorous footing, defining what is being studied, what counts as reliable evidence and other related questions (Cohen, Manion & Morrison, 2000).

3.2. Differences between Research and Evaluation

The central questions in research and evaluation differ. Research is more universal and focuses on internal and external validity, while evaluation is guided by value questions and focuses on utility and credibility (Babbie & Mouton, 2001). An evaluation Case Study still has to strive for internal and external validity as far as possible.

3.2.1. Internal validity

Internal validity of qualitative research depend on a number of factors, such as the ability of the research to report on issues through the eyes of the participants; through a sound research design; through the use of data that is dependable and confirmable (LeComte & Preissle, 1993). Further, the findings should be exposed to a debriefing of a disinterested peer to test honesty, the working hypothesis and identifying the next steps in the research, as well as efforts to offer respondents to add further information and to correct factual errors; there should be triangulation of findings (Lincoln & Guba, 1985).

Interim findings were presented to the Mathematics lecturers' focus group, to the Foundation staff of 2005, to a Mechanical Engineering department meeting of all

lecturing staff, as well as to individual lecturing staff in this department to comment on, to check and shape the direction of the evaluation. Findings were triangulated through various means (see section 3.6.3. below).

3.2.2. External validity

Care should be taken to guard against the use of positivist methods to check generalizability of findings from an interpretivist standpoint; rather sufficiently rich data should be provided for readers and users of research to determine whether transferability (generalizability) is possible (Lincoln & Guba, 1985). This is further justification for the use of a Case Study approach for this evaluation.

3.3. Selecting a paradigm for the Study

There are three main paradigms in evaluation research, namely experimental, qualitative/ naturalistic, and a participatory or empowerment approach (Mouton & Babbie, 2001). These methodological paradigms are closely aligned with sociological correspondents, ie positivist (experimental), interpretivist (qualitative / naturalistic) and critical (empowerment) paradigms (Cohen *et al*, 2000).

Evaluation for improvement differs from other evaluations in that its primary purpose is not summative. The Foundation programme under review commenced in 2002, with the first phase of its implementation terminating at the end of 2006. A summative evaluation would only have been possible, at the earliest, after the 2006 Foundation student cohort completed its first semester of the mainstream Diploma in Mechanical Engineering, ie after July 2007. In addition, the second phase of implementation of the Foundation programme commences at the start of 2007. With, this in mind and noting that the evaluation study commenced in 2005, it was more appropriate to conduct an evaluation study for improvement. The findings and recommendations of this study could then feed into the process of setting up of phase two of the Programme. Evaluation for improvement places greater emphasis on a formative approach (Babbie & Mouton, 2001). This means a focus more on the conception, design and implementation phases of a programme, than on its impact. The evaluation for improvement is also not about the extrapolation of principles, nor about building new models or theories (Patton, 1997). This Study is thus more about evaluating the Foundation Mathematics course against a backdrop of existing theory. The type of evaluation approach chosen will necessarily influence the paradigm of the Study.

The positivist approach is not accepted as it is difficult to set up experimental groups within classrooms. The application or non application of certain approaches have ethical considerations. How does one, for example, justify the continued use of a method that appears to work well, exclusively with one group while the other is left with a relatively 'inferior' method? Positivism has been described as mechanistic and reductionist (Cohen *et al*, 2000).

The critical paradigm is not accepted as the main framework for this study as the researcher would be bound to critique the power relations and ideological interests within which the teaching and learning finds itself (Cohen *et al*, 2000). The focus of this study is to interpret the inner workings of the Foundation Mathematics course; thus an interpretivist framework appears to be the most suitable (Cohen *et al*, 2000). This is further supported by what Habermas (1984: 109) calls a 'double hermeneutic' that belongs to the interpretivism paradigm, namely that people strive to interpret and operate in a world that is already interpreted. As the study sets itself as evaluation with the aim of improving the course this Study has to not only critically examine the inner workings of the Foundation Mathematics course but also come up with suggestions for improving it. Thus, while the Study is in the main from an interpretivist perspective, it has to have a footprint in the critical paradigm.

An interpretivist paradigm has been criticized for being limited in that interviewees are generally limited in their knowledge and that sense still needs to be made of what is being said (Giddens, 1976). One of the aims of the interpretivist paradigm is to uncover meanings which are sometimes taken for granted. The criticism by Giddens does not negate the interpretivist paradigm but rather highlights a crucial element thereof. No verbal account can ever be complete and may contain errors (Bernstein, 1974). This important consideration raised by Bernstein does not negate the interpretivist methodology but rather points to its limitations. Care should be taken to triangulate data where possible as well as consider data gathering over an extended period of time, rather than at an isolated moment. Bearing in mind the criticisms of the interpretivist methodology, it is selected, nevertheless, as being the most appropriate for the requirements of this Study.

The methodology for any research has to rest firmly on an appropriate paradigm. For the purposes of this Case Study the interpretivist paradigm has been selected as the most suitable.

3.4. Why the interpretivist paradigm?

The Interpretivist paradigm is informed by naturalistic inquiry (Cohen *et al*, 2000). Data is socially situated and dependent on their context. In line with the aims of evaluation to describe phenomena, the interpretivist paradigm is idiographic rather than nomothetic. Naturalistic inquiry examines situations through the eyes of the participants and should provide 'thick descriptions' of contextual behaviour (Geertz, 1973). Using the naturalistic framework is a suitable tool for evaluating an integrated curriculum. Qualitative data distilled from naturalistic inquiry may be used to cross-validate the academic literacy theory which is the basis of the integrated curriculum model being evaluated in this Case Study (Campbell, 1988). The use of approaches to learning theory in conjunction with academic literacy theory may also provide insight into reasons for student cognitive difficulties in Higher Education (Marshall & Case, 2005). This would set the basis for recommendations for improving the Foundation Mathematics course. The framework of the conceptual model for the integrated curriculum in Mechanical Engineering (Figure 4.1), sets the focus for the Study and is consistent with the implications of selecting an interpretivist paradigm for the Study (Lincoln & Guba, 1985). The use of naturalistic inquiry, although this is not exclusive to this method, tends to favour the collection of qualitative data and the use of grounded theory analysis (Cohen *et al*, 2000). This means that the data gathered suggested the theory and provided a valuable method for evaluation against the backdrop of the theoretical predictions of an integrated curriculum.

3.5. The scope of the evaluation for improvement case study

This 'evaluation for improvement' Case Study (Babbie & Mouton, 2001; Rossi & Freeman, 1993) addresses the conceptualization and design; the implementation and impact of curriculum integration of Foundation Mathematics into Foundation Science within the Department of Mechanical Engineering at a University of Technology, CPUT. This Evaluation Study is conducted with a view to improving the mathematical component of the Foundation provision of the National Diploma in Mechanical Engineering at CPUT. The Foundation Programme/provision was set up to improve the first year pass rate and throughput in the said Diploma programme in Mechanical Engineering (Jacobs & Jacobs, 2003).

For the purpose of the evaluation, a framework of the four main research questions (Conceptualisation, Design, Implementation, Impact) was set up (Table 3.1):

Table 3.1 Framework for the evaluation case study on integration

WHAT IS TO BE EVALUATED	WHY SHOULD IT BE EVALUATED	EVALUATION QUESTIONS
<p>CONCEPTUALISATION</p> <ul style="list-style-type: none"> - Conceptual model - Integration and disciplinarity of Foundation Mathematics (FM) with Foundation Science (FS) 	<p>To assess:</p> <ul style="list-style-type: none"> <input type="checkbox"/> The conceptual model itself and its associated learning approach(es) <input type="checkbox"/> Staff responses to the conceptual model of integration of FM into FS <input type="checkbox"/> Student responses to the conceptual model of integration of FM into FS 	<ol style="list-style-type: none"> 1. What is the conceptual model of the Foundation Programme (FP) and what is/are the learning approach/es associated with it? 2. How did staff experience integration and disciplinarity? 3. How did students experience integration and disciplinarity?
<p>DESIGN</p> <p>What was the plan for the conceptual model to be implemented?</p> <ul style="list-style-type: none"> - Content - Outcomes - Materials 	<p>To assess:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Did the design match the conception? <input type="checkbox"/> Issues of 'equivalence' with the mainstream course <input type="checkbox"/> How students are supported 'horizontally' (FM into FS)? <input type="checkbox"/> How students are 'vertically' prepared in FM for further study? <input type="checkbox"/> Effect/affect of materials on student learning 	<ol style="list-style-type: none"> 4. Did the design match the conceptual model? 5. What learning approach/es is/are associated with the design? 6. Did students achieve equivalence with the mainstream courses? 7. How do students relate to mainstream students? 8. Are horizontal and vertical objectives compatible? 9. How did staff experience the materials? 10. How did students experience the materials?
<p>IMPLEMENTATION</p> <ul style="list-style-type: none"> - Selection of students - Selection of staff - Management, co-ordination and administration 	<p>To assess:</p> <ul style="list-style-type: none"> <input type="checkbox"/> How students were selected for the FP <input type="checkbox"/> How staff were selected for the FP <input type="checkbox"/> The effect of logistical issues on the implementation of integration of FM into FS 	<ol style="list-style-type: none"> 11. How were students selected/orientated? 12. How were staff selected and trained/ supported? 13. How do FP staff relate to each other and to mainstream staff? 14. What caused practical problems? 15. How were they addressed? 16. What learning approaches were associated with the way the integration was implemented?
<p>IMPACT</p> <ul style="list-style-type: none"> - On teaching 	<p>To assess:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Facilitation of learning <input type="checkbox"/> Student perceptions of 	<ol style="list-style-type: none"> 17. How did the staff integrate FM into FS- why? 18. How did the students' experience

<p>- On learning</p>	<p>teaching</p> <ul style="list-style-type: none"> □ Students academic performance □ Affective factors influencing learning 	<p>this integration of FM into FS?</p> <p>19. What was taught (intentionally and unintentionally)?</p> <p>20. What were the academic results?</p> <p>21. What did students learn (intentionally and unintentionally)?</p> <p>22. What learning approach(es) was/were associated with the model in practice?</p> <p>23. How do the students feel about the integration of FM into FS?</p> <p>24. How do the students feel about the FP?</p>
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3.6. The methodology used

The method chosen to evaluate the integration of Foundation Mathematics into Foundation Science was driven by the framework (Table 3.1) and by the data available to the researcher. The next step was to select an appropriate time frame for the Case Study.

3.6.1. The timing and time frame of the evaluation

An ideal evaluation starts with setting up of a programme, continues together with it and ends after its completion (Babbie & Mouton, 2001). The evaluation team would then be able to give formative feedback on a continuous basis. Ongoing evaluation of the coherence of the model could then also be given.

The Foundation programme under review commenced in 2002 (Jacobs *et al*, 2002), with the first phase of its implementation ending at the end of 2006. The next phase of the programme intervention is at the start of 2007. There is no break of any significance between the first and second phases. A formative evaluation study (Evaluation for improvement) has a more open and flexible design (Babbie & Mouton, 2001). It is better to have a retrospective longitudinal evaluation from 2002 to 2005 than to have based the evaluation on only one year as it opens the possibility to explore causal relationships (Cohen *et al*, 2000). It is important to have not included 2006 in the evaluation as the final evaluation would be written up in this year. This would give a greater measure of objectivity to the process. Further, a Study since the start of the programme would enable a focus on a particular aspect, in this case, integration of Foundation Mathematics into Foundation Science. There would be prospects for establishing causal relationships, although this may be complex and not easy to identify (Douglas, 1976). Evaluating up to 2005 would also enable early

input into the design and implementation of the Foundation programme for the phase starting in 2007. It was thus decided to limit the scope of the research. Thus, this study focuses on curricula, as well as staff and student participation in the Foundational provision of the Diploma Programme within the Mechanical Engineering Department of CPUT (Bellville campus) between 2002 and 2005. A section of industry was also interviewed.

3.6.2. The use of qualitative data

Qualitative data forms the basis of this case study, which uses quantitative and qualitative data as a means of triangulation. As it was necessary to investigate the conception, design, implementation and impact of the model of integration being used as well as the corresponding learning approaches that went with each of these stages, the study relied on focus groups, in-depth interviews, records of Foundation lecturer planning discussions on integration, departmental feedback sessions (where interim research results were presented) and documentary evidence.

There are various categories of focus groups. The exploratory (Fern, 2001) focus group was deemed unsuitable for the study as its aim is to generate new theoretical constructs. The experiential focus group was used as it can be used to evaluate models or theories (Calder, 1977). The experiential focus group relies on a pre-determined population and examines language, knowledge and experience. The pre-determined population in this case was each cohort of Foundation students from 2002 to 2005. The group of six Foundation lecturers, the four Mathematics lecturers, the group of 3 Mechanics lecturers, were all pre-determined populations. Cross validation (Campbell, 1988) of existing theory has to take into account observations, and consistency with it. The experiential focus group can be used to uncover an explanation for a shared experience, in this case, of the curriculum integration model (Fern, 2001).

There are a number of factors to be taken into account to ensure that the quality of the data is not undermined:

Group cohesion

Group cohesion – this is the sense of closeness and common purpose among the group (Davis, 1969). The common thread that unites the individual focus groups is their respective common experiences on the Foundation Programme.

Process

The process is crucial and should involve social integration, mirror reaction, condenser phenomenon and exchange (Foulkes, 1964). Social integration involves ensuring that all members of the focus group participate; mirror reaction involves relief of anxiety on realising that another group member shares a similar experience; condenser phenomenon involves the activation of a collective conscious or subconscious; exchange involves the process of information sharing and not allowing the group dynamic to be destroyed. Integrity of process was assured by the emphasis that the evaluation was formative and that other future student cohorts stood to benefit from the research, when new issues arose in the discussion the researcher ensured that all members of the group stated their opinion.

Group composition

Group composition – factors to be considered were cultural value/orientation, age, gender, social status, race/language, personality (Altman, 1975; Lincoln & Guba, 1985). The researcher selected with consideration to having a spread of home languages, ensuring that male and female students were present in all cohorts, age was not an issue as students of the same cohort were of similar ages, all were students so the question of social status was satisfied. The only cohort which did not meet all the criteria was the 2003 cohort which were all male and of one language group. The researcher had taken steps to invite female students as well as students of other language groups but they did not turn up for the scheduled focus group. It was decided that more would be gained from going ahead with this focus group, despite the limitations. For the purpose of this study the researcher added another factor, namely academic performance. This meant that all student cohorts had a spread of students who had either not repeated any subjects to students who had repeated subjects several times. The Mechanics, Mathematics and Foundation staff focus groups included all members of the subgroups as the numbers were small and exclusion of one or more would have limited the richness of the data.

The setting

The setting, which includes giving optimum privacy and personal space need to be considered (Altman, 1975). The student focus groups were conducted a classroom setting with the chairs arranged in a circle. Permission was sought by the researcher for the use of a tape-recorder and guarantees of anonymity were given to group participants. Where hesitancy was shown the tape-recorder was not switched on until the entire group felt at ease. The researcher offered to switch off the recorder at any

stage during the discussion. Once the purpose of the focus group was clarified and re-emphasised, the groups generally agreed with the tape recording of the session. (The only groups that showed some hesitancy were the 2004 student cohort and the Foundation staff group). The same precautions were taken in all focus groups but the lecturer groups took place in the department staffroom.

The use of a moderator

The use of a moderator in focus groups is not always necessary and may even, in some cases, be harmful (Fern, 2001). The researcher decided not to use a moderator as it could have interfered with the group dynamics. There was some reluctance on the part of participants prior to the focus groups and the presence of an 'outsider' may have influenced the data.

Group process

Group process- inherent in groups are tendencies of participants to forget, to be distracted by other members or to rehearse what they are going to say. This means that focus group data should be triangulated for reliability(Fern, 2001). Triangulation is dealt with below.

Size and number of focus groups

A rough guide to the number of focus groups to be held are four to six, dealing at no more than 12 points as participants tend to deal with the most salient ones first (Fishbein & Ajzen, 1975). Respondents (group members) should also be recruited by the researcher. The researcher held seven focus groups, which is within the scope that is required. Even though the questionnaire (Appendix A) was used as a guide, less than 12 questions were posed to the focus groups. The 2005 student focus group brought an extra 2 students than were invited by the researcher. These students were also Foundation students from the cohort of 2005 and the number in the group was seven, still well within the 4-12 range proposed by Morgan and Krueger (1998) for the optimal focus group size. As all the members of the focus group were at ease, the session with the 2005 cohort went ahead. The only focus group that had insufficient numbers was the Mechanics focus group and the data from it was treated as an in-depth interview.

Relation of researcher to group interaction

Reliance on interaction on a topic supplied by the researcher (Morgan & Krueger, 1998)- the researcher provided the topic, namely integration of Foundation

Mathematics into Foundation Science, and guided discussions at times when sight was lost of the focus.

Table 3.2 Sample focus group questions

Sample focus group questions
1. What do you understand by integration of Maths into Science?
2. What kind of activities would you be doing?
3. What did you learn from this?
4. Give a brief indication why you decided to do Mechanical Engineering?
5. Did integration help you make up your mind?
6. Should there be more integration? Specify
7. Any bad experience? Specify

The researcher concluded that the focus group data had integrity and the discrepancies were not fatal. There was still the need to triangulate this data for reliability (Morgan & Krueger, 1998; Diehl & Stroebe, 1987).

Table 3.3 Focus group size

Focus group	Number of participants
Student cohort 2002	5
Student cohort 2003	4
Student cohort 2004	5
Student cohort 2005	7
Foundation lecturers 2005	6
Mathematics lecturers 2005	4
Mechanics lecturers	3

A limitation of experiential focus groups is that it is difficult to generalise beyond the population of interest (Fern, 2001).

The researcher also used in-depth or focused interviews (Table 3.4). These may be used when the interviewee is known to have been a participant and where content analysis has led the researcher to test an idea or hypothesis (Merton & Kendall, 1946). (A content analysis of focus group data led the researcher to question the conceptual choice of EMS as the 'core subject' for integration). In these cases the interviewer could bring out affective and value-laden implications on subject matter

(Ashton, 1994). The approach to these in-depth interviews was more 'narrative' on the topic provided by the researcher, namely integration. Enabling the research participants to 'tell their stories' is an important key to producing deep, rich data (Labov & Waletzky, 1967). When participants 'change mode' – from answering formal interview questions to an informal, relaxed 'storytelling mode' – they produce elaborate narratives, which often contain important insights (Labov, 2001).

Individual interviews were also conducted with 5 ex- Foundation students who had completed the 4 semesters of their theory part of their studies and who only had in-service training to complete for them to attain their Diplomas in Mechanical Engineering. They were encouraged to speak in an open-ended fashion to reflect on their experiences in their respective Foundation year of study.

Twenty companies were interviewed, from local engineering firms to national and international companies with engineering departments, to gather data both on the mathematical thinking skills needed for success in industry and on the shortcomings of in-service students and engineering graduates.

Table 3.4 List of one-to-one interviews

In-depth interviews	Sector/subject
20 interviews one-to-one	Engineering companies or companies with engineering divisions
One-to-one	2 EMS lecturers; 1 EMS moderator; 1 manufacturing specialist; 1 design specialist
One-to-one	5 in service ex Foundation students from the cohorts of 2002 and 2003

As the outcomes of the research are negotiated, the researcher has to bear in mind the tension between interviewer and interviewee, which could affect the data produced (Riessman, 1993). The researcher also needs to remember that the data produced is not a direct indication of reality but is 'narrated' information (Deuten & Rip, 2000) – so triangulation is necessary to ensure validity. This leads directly a discussion of the steps taken by the researcher to triangulate the qualitative data gathered.

3.6.3. Triangulation

The first problem with longitudinal studies is that of sample mortality (Cohen *et al*, 2000). Many of the Foundation students from the years 2002 to 2004 had left the University due to various reasons (exclusion for academic or financial reasons among others). This may have weakened the data but does not preclude an evaluation being successfully being completed.

Triangulation of data may be achieved by one-to-one interviews, questionnaires, observations, documents and by statistical means (Morgan & Krueger, 1998; Diehl & Stroebe, 1987):

The use of an earlier evaluation

Triangulation of data is partially achieved by the critical use of an Evaluation Study conducted in June 2002 (Jacobs *et al*, 2002) and by the use of questionnaires that had been issued and filled in by Foundation students during 2003 (Appendix C) and 2004 (Appendix B). Verbal data from the 2005 questionnaire (Appendix A) was also used.

The use of statistical methods

The application of statistical methods to the marks of the students was also used as a means to triangulate trends that emerged in the data. A 2-tailed t-test paired for means, comparing Matric mathematics with Physical Science results and comparing this with 2-tailed t –tests comparing Foundation mathematics marks with Foundation Science, S1 Mechanics and S1 Mathematics, respectively, for each student cohort were used to triangulate for trends that academic literacy and learning approach theories may have predicted.

The statistical means of Ex-Foundation cohorts with mainstream cohorts for each year of the case study, against predicted trends that academic literacy and learning approach theories may have predicted. Due to the problems around examinations (Case & Marshall, 2004; Sazhin, 1999) student marks were used with at least one other factor (such as one-to-one interviews, documentary evidence) to triangulate data.

The use of one-to-one interviews and documentary evidence

Verbal data that arose from focus groups that raised questions of the conceptual model of integration, were triangulated through one-to-one interviews with EMS lecturers and a moderator, as well as documentary evidence.

The use of Muddy cards

A 'Muddy card' was used to triangulate for some of the data from the 2005 student cohort.

(A 'muddy card' is the opportunity that students are given to give feedback to the facilitator/lecturer about any selected teaching and learning activity, such as an assessment, a practical, a lecture. Students are given blank pieces of paper to write comments on. It is an opportunity to figuratively 'throw mud' at any practice that they feel unhappy about, or to give positive feedback or if they have no comment, the paper would be left blank. If they are satisfied and do not want to comment, they could also write 'no mud' on the paper. The pieces of paper, normally filled in anonymously, are usually collected by a class representative and handed in to the facilitator/lecturer. 'Muddy cards' are normally handed out at the end of the activity being evaluated by the student. The Department of Mechanical Engineering, in 2005, adopted this practice currently being used at the Massachusetts Institute of Technology (MIT).)

The use of documentary evidence and transcripts of planning sessions

Departmental documents, journal articles and transcripts of staff planning sessions were used to add depth to the narrated data (for example Appendices J-N).

The use of questionnaires

Judicious use of questionnaires to the Foundation students and to lecturing staff in the Mechanical Engineering Department were used to supplement the narrated data (Appendices A-D).

Presentation of interim findings

Progress reports of interim findings were presented and discussed in staff meetings and the Mathematics lecturer focus group, of the department of Mechanical Engineering (that is part of this Study).

The use of integration-related documents

Course documents and documents on integrated assignments were used to add depth and triangulation of data (for example Appendices P-EE).

Problems of people forgetting, of possibly suppressing or of interpreting their past in the light of past events (Cohen *et al*, 2001) was also countered through triangulation. For some aspects of the study it was useful for students to reflect on their experiences after their 'Foundation year', to begin to gauge the 'success' of the Programme but also to allow for shortcomings to come into sharp focus (the cohort samples from 2002 to 2004 could compare their Foundation preparation with their experience in mainstream study).

The researcher had to take further steps to enable this study to be consistent with the methodological principles of evaluation research (Babbie & Mouton, 2001).

3.6.4. Standardization of the data collection procedures

The following steps were taken to attempt to create a standard or norm to guide the data collection procedures:

1. The researcher conducted all the interviews;
2. The student cohort focus groups (2002-2005) each used the same questionnaire (Appendix A) as a guide for the discussions;
3. The interview sessions of the student focus groups, the Mechanics lecturer focus group, the Mathematics lecturer focus group, the Foundation staff focus group and the departmental feedback were all tape-recorded and the interviews transcribed. All other interviews were recorded by the researcher and minutes prepared of all of them;
4. The companies were all asked the same questions (see Appendix O);
5. Geographic location did not play any part to vary the data as all the interviews (barring the ones with the companies), were conducted in a venue in the Department of Mechanical Engineering;
6. Verbal data was analysed following Geisler's (2004) system of coding for thematic interpretation.

3.6.5. Analytical Method

Statistical analytical methods were applied to the assessment records to assist in analyzing the impact of the integration of Foundation Mathematics into Foundation Science as well as a means to triangulate trends that emerged from the qualitative analysis. The Tertiary Education Linkages Project (TELP) test results were excluded as marking was inconsistent and there were errors in the memoranda (Sheikh, 2004). (The TELP tests were set up as part of a national initiative to develop an entrance test that could identify 'at risk' students and/or be used for placement in programmes. These tests were typically taken by students either before entry or within two to three weeks upon entry into tertiary level study). Content analysis was applied to the verbal data gathered to look at:

1. Achievements
2. Strengths
3. Weaknesses
4. Constraints

The specific approach to data collection must be seen in conjunction with the framework outlined in Table 3.1 above.

3.6.6. Research question 1: How was the integration of Foundation Mathematics into Foundation Science conceptualized and designed?

Here the main source of data was the curricular planning documents; journal articles; focus group and individual interviews with the programme developers, lecturing staff and student cohorts; interviews with industry and the governing body of the Department of Mechanical Engineering at CPUT.

Types of data

The type of data gathered was in verbal form (written descriptions or explanations of the curriculum; an evaluation study conducted in 2002 was studied; texts of the Foundation Mathematics, Foundation Science and Mechanics 1 courses).

Information was gathered with respect to the rationale for integration, sequencing, for the texts as well as the tasks designed; interviews with industry as well as the governing body of the Department of Mechanical Engineering at CPUT; questionnaires to and interviews (Focus groups and one-to-one) with students and lecturers.

Unit of analysis

The unit of analysis was the same for each of the 3 broad research questions:

1. Integration: Statements about integration
 Statements about the integration of FM into FS
 Perceptions about the integration of FM into FS
 Attitudes towards the integration of FM into FS
 Implied understanding of the integration of FM into FS
 First year student issues related to integration

The use of learning approach theory in conjunction with academic literacy (Marshall & Case, 2005) means that a further coding of the data has been performed. This is to help establish association of aspects of learning approaches with integration. This is a step towards establishing causality, as there can be no causality without association (Strauss & Corbin, 1998). By considering the process of implementation of integration and when such interventions occur, aspects of precedence may be established. One cannot say that A causes B without establishing that A precedes B (Strauss & Corbin, 1998).

A further unit of analysis arises: Is there any association with the each of the above units of analysis on integration with learning approach theory?

A sample of this further coding is given in Table 3.5 below.

Analytical method

The method analysis for the data gathered was in the form of content analysis, to answer the questions 1-10 in Table 3.1:

1. What is the conceptual model of the Foundation Programme (FP) and what is/are the learning approach/es associated with it?
2. How did staff experience integration and disciplinarity?
3. How did students experience integration and disciplinarity?
4. Did the design match the conceptual model?
5. What learning approach/es is/are associated with the design?
6. Did students achieve equivalence with the mainstream courses?
7. How do students relate to mainstream students?
8. Are horizontal and vertical objectives compatible?
9. How did staff experience the materials?

10. How did students experience the materials?

Verbal data was analysed for all 3 Research questions following Geisler's (2004) system of coding for thematic interpretation (See Table 3.5 for examples):

Table 3.5. Sample coding for thematic interpretation

Transcript	Key word/s	Code (Academic literacy)	Second Code (learning approach)
How to generate ideas, how to go through that process, a method	Ideas, process, method	Learning as a process	metacognition
You learn a lot, know how to work in a group do practicals how to do calculations	Learn a lot, group work, practicals, calculations	Cognitive development with group work and integration	Recognition level of reflective abstraction
A lecturer might say that he/she only focuses on his strengths, and may only understand his field.	Lecturer strengths... field	Negative evaluation: lecturer strength only in field	Lack of equivalent understandings of concepts
You started to think... why do doors open that way... why do handles turn that way	Why doors open, why handles turn	Internalisation of concept	Structural awareness as concept no longer associated with original calculations.

3.6.7. Research Question 2: How was the integration of Foundation Mathematics into Foundation Science implemented?

The main sources of data to answer this question were the curriculum documents; discourse based interviews with lecturers in the Mechanical Engineering department; focus group interviews with students who had taken the Foundation Mathematics course; Focus group interviews with the Foundation lecturers, the Mathematics lecturers and in depth interviews with students, with Mechanics and EMS lecturers and moderators; questionnaires to students and lecturers.

Types of data

The type of data gathered was in verbal form (written course outlines; texts; tasks set including assessments; timetables; verbal clarification on the course outline, texts, notes and assessments as well as on the implementation of the course).

Unit of analysis

The Unit of analysis was the same as in 3.6.6. but from the perspective of Research Question 2 on implementation of integration of FM into FS.

Analytical Method

The method of analysis of the data gathered was in the form of content analysis, to answer questions 11-16 in Table 3.1:

1. How were students selected/orientated?
2. How were staff selected and trained/ supported?
3. How do FP staff relate to each other and to mainstream staff?
4. What caused practical problems?
5. How were they addressed?
6. What learning approaches were associated with the way the integration was implemented?

3.6.4. Research Question 3: What was the impact of integration of Foundation Mathematics into Foundation Science?

Data for the impact of integration of FM into FS were sourced from assessment and attendance records; lecturer focus group interviews; student focus group interviews; interviews with industry as well as the governing body of the Department of Mechanical Engineering at CPUT; questionnaires to students, lecturers and industry.

Type of data

The type of data gathered was in both numerical and verbal form (affective impact).

Unit of analysis

The unit of analysis used was the same as for 3.6.6. but from the perspective of Research Question 3, namely on the impact of the integration of FM into FS.

Analytical method

The method of analysis of the data gathered was in the form of content analysis, to answer questions 17- 24 in Table 3.1:

1. How did the staff integrate FM into FS- why?
2. How did the students' experience this integration of FM into FS?
3. What was taught (intentionally and unintentionally)?
4. What were the academic results?
5. What did students learn (intentionally and unintentionally)?
6. What learning approach(es) was/were associated with the model in practice?
7. How do the students feel about the integration of FM into FS?
8. How do the students feel about the FP?

Section 3.6. explained the analytical approaches and methods used in the case study, the next section addresses ethical issues, including permissions, for this study.

3.7. Ethical issues

No Evaluation Case Study would be complete without due attention to ethical considerations. Research may impact on the rights, values and dignity of the participants; its procedures may cause anxiety especially if it deals with personal and sensitive information and may generate feelings of disempowerment (in cases such as where participants may be from a particular group, for example, disadvantaged students)- appropriate steps should be taken to balance the rights of participants with the needs of research (Frankfort-Nachmias & Nachmias, 1992; Cohen *et al*, 2000).

Evaluation Studies have particular ethical considerations that have to be kept in mind (Babbie & Mouton, 2001; Cohen *et al*, 2000; Evaluation Ethics, s.a.).

The first consideration is to obtain permission from Institutional committees. The Higher Degrees Committee of the CPUT granted permission for this Evaluation Study to be conducted. As part of this process, the permission was first sought and granted from the Engineering Faculty Research Committee, under whose jurisdiction the Department of Mechanical Engineering resides, where this Study was conducted (Appendix PP).

The second consideration is for the needs and sensitivities of the respondents. All persons being interviewed were assured of their anonymity beforehand. Sessions were only tape recorded where respondents were satisfied that their anonymity was guaranteed. A process of feedback into the department of Mechanical Engineering was agreed upon. This included feedback sessions where members of the department gave critical comment that forms part of this Study. The final report has to be presented to the department upon completion. Respondents were also invited to return questionnaires anonymously via a representative of their choice as part of a technique to elicit data to attenuate the 'halo effect' (The researcher had been the Foundation Mathematics lecturer for all student cohorts that formed part of the period delimited in this study). 'Muddy cards', which have been used in this study, were filled in anonymously by respondents and handed to the researcher by their class representative.

Lastly, interviews were conducted during lunchtimes or at times when respondents were not involved in classes. In other words, care was taken not to disrupt respondents' academic activities.

3.8 . Conclusion

The above research methodology is used to provide the framework for the main argument of this thesis, namely that conceptual and design flaws in the integration model led to student learning of Mechanics concepts not being effectively supported. This leads directly to the next Chapter which elaborates the research findings on the conception and design of integration of Foundation Mathematics into Foundation Science.

CHAPTER 4

EVALUATING THE CONCEPT AND DESIGN OF THE INTEGRATED MATHEMATICS COURSE

4.0 Introduction

This Chapter presents the research findings on the evaluation of the overall conception and design of the Mechanical Engineering Foundation Mathematics course. It starts with an evaluation of the conceptualisation of the Foundation programme. The findings on the conceptualization of the Foundation mathematics course, within this context are then discussed. The latter part of the chapter deals with the findings on the evaluation of the design aspects of the Foundation programme and of Foundation Mathematics within this context. Course concept refers to the thinking or rationale behind its structure while course design refers more to the plan for this thinking or rationale to be implemented. The Chapter ends with a summary of the findings against the background of the literature on academic literacy and learning approach theory.

4.1. Conceptualisation of the Mechanical Engineering Foundation programme

This section presents the findings on the FM course within the conceptual model for integration of the Foundation Programme. It is important therefore to clarify what is meant by vertical -and horizontal integration.

Horizontal integration

Horizontal integration means support for subject matter within other courses at the same level. In this case, horizontal integration within the Foundation Programme means support for subject matter in courses covered within the Foundation year.

Vertical integration

Vertical integration means support for subject matter within courses at the next or higher levels in a Programme. In this case, for example, vertical integration of FM means support for the next level of mathematics, namely S1 Mathematics of the

mainstream MDIPME programme. Vertical integration of FS means support for the next level subject within the mainstream MDIPME programme, namely Mechanics 1.

4.1.1. General first year factors

The Foundation Programme in the Department of Mechanical Engineering at CPUT was set up in response to a need to improve pass rates at first year level and throughput for the National Diploma in Mechanical Engineering (MDIPME) programme (Jacobs & Jacobs, 2003). The Foundation programme was thus intended to address factors that hamper entry-level student performance at tertiary level within a specific programme (Mechanical Engineering).

4.1.2. Conception of the integrated curriculum for the Foundation programme

It (the Foundation programme) was conceptualized as a fully integrated programme (see Figure 4.1 below) in which a core mainstream subject, EMS, is supported by 'literacy' and 'numeracy' courses, which include Mathematics and Science (Jacobs *et al*, 2002). Another mainstream subject included was Computer skills, which was largely supportive of all subjects as it is of itself a support course for the normal mainstream first semester. In the second half of the year, the course Engineering Manufacturing Skills (EMANS) replaces EMS as the core course.

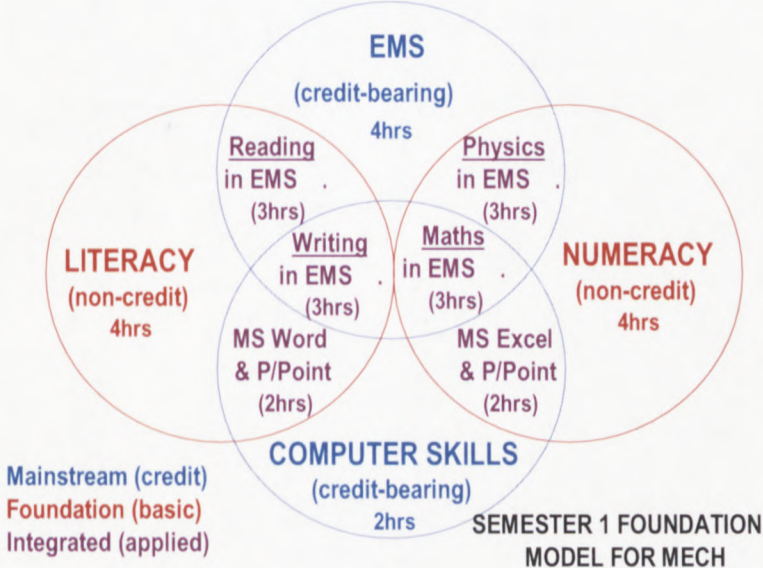


Figure 4.1 Model of the Mechanical Engineering Foundation programme – adapted from Jacobs *et al* (2002)

The number of hours reflected in Figure 4.1. represents the weekly contact time between lecturers/facilitators and Foundation students. Further, the red circles represent the Foundation level courses with Numeracy comprising both FS and FM courses. The blue circles represent the Mainstream courses that were part of the Foundation year. The purple text represents the 'integrated' activities where support was given for concepts in the EMS Mainstream course. The term 'applied' refers to activities where support from a course or courses is/are given to one or more other courses.

The EMS course for the Foundation students was conceptualized to be different from the mainstream EMS course. Its outcomes were to be substantially more general, including aspects of Mechanics, Thermodynamics and Fluid Dynamics, among others (See Table 4.1 below and Appendix J). Appendix J shows that the mainstream EMS course was based purely on the science of materials, while the Foundation EMS was conceptualised as being more general.

Table 4.1: Comparison between course content of Foundation and Mainstream EMS courses

Foundation EMS: Course outline	Mainstream EMS: Course outline
Context – the role of mechanical engineers in society, etc	Context- the inter-relationship between mechanical engineers and material scientists
Underlying concepts in mechanical engineering (Strength, Fluid Dynamics, Thermodynamics, Mechanics, Density, Stress, Strain, Humidity, Vapour, Liquid, Steam, Work, Air, Refrigerants, Beams, Rate of change, etc.)	Stress, strain, elasticity
Categories of materials	Categories of materials
Important mechanical tests (Tensile, torsion, hardness, impact, creep, fatigue – with detail on 'hardness test' and time dependent tests – creep and fatigue)	Important mechanical tests (Tensile, torsion, hardness, impact, creep, fatigue – with detail on 'hardness test' and time dependent tests – creep and fatigue)
Fracture - causes and avoidance	Fracture - causes and avoidance
Working with metals Hotworking and coldworking –eg annealing age and precipitation hardening strain hardening rolling, drawing and bending residual stress	Working with metals Hotworking and coldworking –eg annealing age and precipitation hardening strain hardening rolling, drawing and bending residual stress
Iron and Steel Introduction to steels	Iron and Steel Introduction to steels

Special steels Surface treatments Weldability Stainless steels	Special steels Surface treatments Weldability Stainless steels
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(adapted from Jacobs *et al*, 2002)

The intended general nature of the Foundation EMS course is demonstrated by the following comment in a departmental feedback session in September 2006 by a lecturer who had been part of the discussions that preceded the programme:

All basic concepts that students usually have difficulty with, such as those of Mechanics, Fluid Dynamics, Thermodynamics, material properties, were supposed to be included in the [Foundation] EMS course (Lecturer Main L01).

This also demonstrated that the conception of the Foundation programme, in the minds of the course designers, had not changed over the period of this study, namely from 2002 to 2005.

Horizontal integration (support for subjects and concepts at Foundation level) was thus conceptualized as support for EMS. Vertical integration was conceptualized as subject-specific, for example Foundation Mathematics preparing students for success in the mainstream, in this case for Mathematics S1 (Jacobs *et al*,2002).

The model was influenced by current research, which challenges the autonomous or 'decontextualised' skills based model (Street, 1984; Gee 1990). Street (1984) proposes a social or ideological model of literacy while Gee (1990) sees literacies as discourses which are historically and socially defined. He refers to the home or primary discourse, which provides a reference point for the secondary discourse. The Foundation programme under review could thus be seen as academic literacy for Mechanical Engineering, or expounding the foundations of Mechanical Engineering in context (Jacobs *et al*, 2002).

4.1.3. Technologists vs Engineers

In order to contextualise the intended outcomes of the Mechanical Engineering Foundation Programme, it is necessary to clarify the intended outcomes of the programme that it is supposed to prepare students for.

The Diploma that the Foundation programme locates itself is the National Diploma in Mechanical Engineering (MDIPME). The expected outcomes for the MDIPME are encapsulated in the Critical Cross Field Outcomes (CCFO's), which are spelt out in Appendix KK1. The main outcome is Applied Competence, which includes practical competence (the ability to 'do'), foundational competence (understanding the 'why' behind the 'do') and reflexive competence (creative and independent thought). This implies that successful MDIPME students have 'reified' (Sfard & Linchevski, 1994) basic engineering concepts and are able to use them in new ways, without having first to refer to the mathematical processes underpinning them.

Fifteen of the twenty companies (engineering or with engineering divisions) interviewed as part of this study, emphasised 'practical' and 'foundational competence' while only five emphasised the need for 'reflexive competence' (Appendix O). One company went as far as saying that only 'practical competence' was necessary. Nine out of the twenty companies interviewed raised concerns over a lack of practical experience among in-service engineering students. This suggests that these students' ability to form engineering concepts is weak. The process of 'reification' of concepts requires 'condensation' to precede it – this requires use of a concept such as when a complicated process is condensed into a form that makes it easy to use and think about (Sfard & Linchevski, 1994). This is also indirectly supported by companies who say that once students are in their service, they learn quickly (Appendix O).

The survey of twenty companies provides evidence that 'practical', 'foundational' and 'reflexive competences' are required by industry and that 'foundational competence' is associated with 'practical competence'. Insufficient 'foundational competence' would inhibit 'reflexive competence' (Sfard & Linchevski, 1994).

The difference between technologists and engineers would appear to be that engineers are specifically required to be able to solve engineering problems through applying mathematical and Mathematics-related engineering sciences from 'first principles' and to be able to apply research methods and experiments (Appendix KK2). Technologists are required to have a more general ability to use science and technology effectively. The depth of mathematical knowledge would appear to be the key difference between the two.

4.1.4. The conception of Foundation Mathematics within the model

Inherent in the presentation of contextualised Foundation Mathematics was

1. a forward looking programme (that is, one that is geared towards course outcomes rather than one that attempts 'remedial' Mathematics);
2. preparation for applied Mathematics within Mechanical Engineering (vertical integration)
3. academic literacy at tertiary level (horizontal and vertical integration)
4. support for other courses at Foundation level through EMS (horizontal integration)
5. the integration of language and content (the medium of the course is in English and the specialized terms or the language of Mechanical Engineering is also in English)

The Foundation Mathematics course could thus be seen as contextualised teaching and learning within Mechanical Engineering. The socio-cultural practices within Mechanical Engineering form the backdrop against which the Foundation Mathematics course is presented.

4.1.5. Polarity- conflicting conceptions of the role and nature of the Foundation EMS course

Both mainstream- and foundation EMS lecturers had different conceptions than the Foundation programme designers of the nature of the course. 'Polarity' (Jacobs, 1989) of different conceptions of the course would have hindered conceptual development or reconceptualisation in Mechanics. (Mechanics formed the bulk of the content of Foundation Science- see Appendix E). This is illustrated by the following statement, made by a mainstream EMS lecturer:

I designed the EMS course for the mainstream. No-one spoke to me before setting up the Foundation EMS course. The Foundation EMS course was supposed to at least have the same outcomes as the mainstream EMS course. The mainstream EMS course is a materials course. Thermodynamics, Mechanics and these topics are huge. There is no way you can do justice to them all in one course. It seems that these were just an add- on. You could take a whole semester with just one of the topics raised. The whole idea of the mainstream EMS course was specifically to give a broader understanding

of Mechanical Engineering that is not normally covered adequately in other courses, namely properties of materials (Lecturer EMS L01).

This position is supported by another mainstream EMS lecturer:

The essence of the [Foundation EMS] course is of the science of materials (Lecturer EMS L03).

The internal moderator of the EMS course similarly confirmed this view, as evident in the following statement:

EMS was a metallurgical course which later developed into a course on stainless steel (Lecturer Mech L02).

This is further supported by a typical assessment of the Foundation EMS course (see Appendix M), where concepts of Thermodynamics, Mechanics and Fluid Mechanics are evaluated in a simplistic descriptive fashion, based on simple recall of 'facts'.

For example, in response to a question in a Foundation EMS assessment, to define equilibrium the answer expected is

equilibrium state - a system is in equilibrium if its properties do not change in value when the system is isolated from its surroundings (Appendix M: Question 4)

The Mathematics and Foundation Science lecturers would have seen equilibrium in terms of a mathematical calculation of vector sums of Forces which has zero resultant and have expected students to have resolved the vectors into components (See Appendix BB). This difference in conceptual expectations from different subject lecturers amounted to 'polarity' (Jacobs, 1989) and would have hindered conceptual development in the minds of the students. This lack of 'equivalence' (Goodsen Espy, 1998) of concepts in the different disciplines, would have hindered concept formation.

During an in-depth interview lecturer (Main L05) changed his view from saying that Foundation EMS was fine as is, to then say that the EMS course had to be changed to include topics like Dynamics, Statics, Energy and Momentum, Work, Energy, Power, lifting machines, friction, heat, particle structure of nature, electricity. The interviewer was referred to a book on N2 Engineering Science by way of further

justification of the lecturer's position (Main L05). 'These topics can be covered in 3 months', he said.

But all of these topics, except electricity, were in the Foundation Science course. Furthermore, the EMS course valued the properties of metals rather than Dynamics, for example. Dynamics and materials science, as it were, belong to different sub-branches of Mechanical Engineering (Figure 4.2). Dynamics was part of Mechanical Systems while EMS was part of Manufacturing Science. Conflicting messages would be a recipe for confusion, hence lecturer (Main) 05's description of foundation EMS as too much materials and too little 'science'. Adding more 'science' and reducing the 'materials' would mean that one no longer had a 'materials' course. Equivalence in outcomes between the mainstream EMS and the Foundation EMS would no longer be possible. If enhancing of the mechanics concepts was necessary before enhancing the 'materials' knowledge, it would have made more sense to make Mechanics the 'core', instead of re-engineering the materials based EMS course.

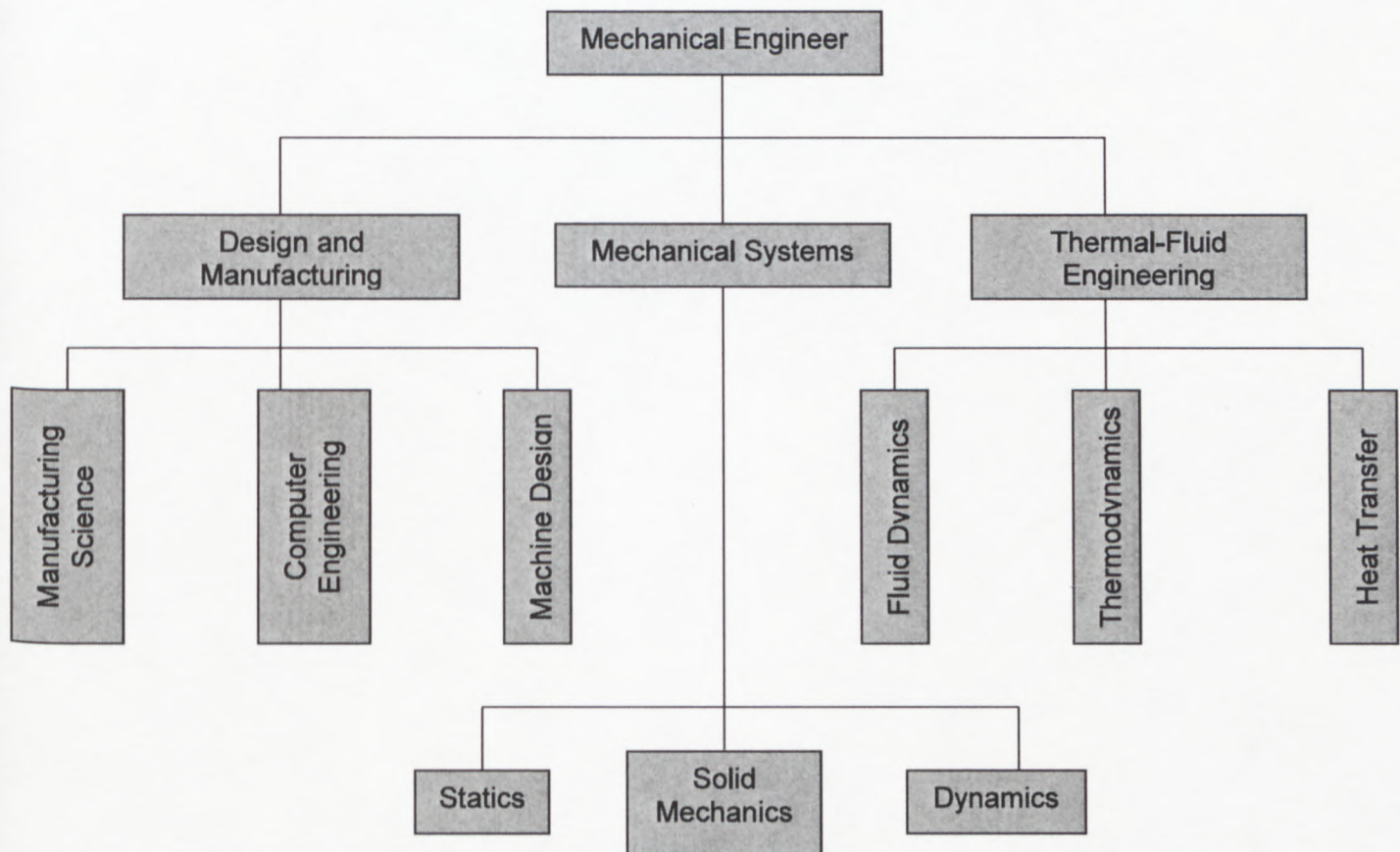


Figure 4.2 Disciplinary specific skills that a Mechanical Engineer should know. Adapted from Wickert (2003)

One of the Mathematics lecturers who had been part of the discussion that led to the setting up of the Foundation Programme raised a different conception of the Foundation EMS course:

I may be wrong but if my memory serves me correctly the centre-piece of the programme was supposed to be Engineering Science and not Material Science
(Lecturer Maths L02).

He explained that Engineering Science was similar in outcomes to the Foundation Science course.

The above findings on the 'polarity' (Jacobs, 1989) of differing conceptions of the Foundation EMS course contradict the findings of an earlier evaluation study (Jacobs *et al*, 2002). The 2002 study found no conceptual disagreement with the Foundation EMS course as the centre around which concepts in Engineering would be supported. A possible source of error in the Evaluation (Jacobs *et al*, 2002) was that the evaluators did not interview the lecturers who had designed the EMS course and they relied on evidence from the Foundation lecturers who had no or very little prior experience in Mechanical Engineering. (See Table 4.2 which shows the training and qualification of the Foundation lecturers).

Table 4.2. Qualifications of Foundation lecturers in 2002.

Lecturer	Qualification
Foundation Mathematics, Foundation Science, Computer Skills	Teachers Diploma (Mathematics and Physical Science)
Foundation EMS	Teachers Diploma (woodworking)
Foundation Communication skills	Teachers Diploma (English)

A constraining factor on the conception of the Programme was that there was a national guideline from the Technikon sector that 2 mainstream diploma courses (from MDIPME) be included in the Foundation programme in order to ensure financial viability (Jacobs & Jacobs, 2003). The Foundation EMS course was constrained to include the outcomes of the mainstream EMS course. This contributed to conceptual 'polarity' between the Foundation course designers and the requirements of the national Technikon sector.

4.1.6. Lack of Affordance

'Affordance' (Kress, 2000) is the compatibility between 2 or more disciplines or subjects. If the key concepts in Mechanics, Thermodynamics and Fluid Dynamics were merely what one of the lecturers termed an 'add-on' (Lecturer EMS L01) to the Foundation EMS, this meant that these concepts could not have been taught in a manner which encouraged deep learning thereof. This lecturer stated that 'it would be impossible (in the EMS course) to teach the basic concepts that students struggle with'. You can always add on 'materials' once students know the Mechanics concepts but you cannot add on the concepts if students know only the Materials Science' (Lecturer EMS L04). Although lecturer EMS L03 agreed that the basic concepts could not be addressed in the same course as EMS, he disagreed with the idea that knowledge of basic concepts could not be taught later.

The necessary time for concept formation would not have been possible (Sfard & Linchevski, 1994). This was borne out by the Foundation EMS lecturer:

I covered the whole of Thermodynamics, Mechanics, Fluid Mechanics, and other basics of Mechanical Engineering in 2 weeks, the rest of the time [13 weeks], I spent on the Science of Materials (Lecturer EMS L03).

Thus, the basic concepts of Mechanics, for example, would not be supported by integration with Foundation EMS as their inclusion was incompatible with a materials course. Indeed, an artificial forcing together of courses with low 'affordance' could make sections or entire courses irrelevant (Jacobs *et al*, 2002). An 'all or nothing' approach was to be avoided (Jacobs *et al*, 2002), meaning in this case that only the relevant sections from Materials Science could be integrated with Foundation Science and/or Mathematics.

This also contradicts the findings of Jacobs *et al* (2002) that there would be many possibilities for integration of EMS with Foundation Science. Their findings on possibilities for integration are found in Table 4.3 below.

Table 4.3: The evaluation findings on Foundation EMS and the possibilities for integration - adapted from Jacobs *et al.* (2002).

Foundation EMS: Course outline for	Possibilities for integrated teaching practices
Context – the role of mechanical engineers in society, etc	Language integration possibilities.
Underlying concepts in mechanical engineering (Strength, Fluid Dynamics, Thermodynamics, Mechanics, Density, Stress, Strain, Humidity, Vapour, Liquid, Steam, Work, Air, Refrigerants, Beams, Rate of change, etc.)	Many Foundation Science integration possibilities.
Categories of materials	Foundation Science and English integration possibilities.
Important mechanical tests (Tensile, torsion, hardness, impact, creep, fatigue – with detail on 'hardness test' and time dependent tests – creep and fatigue)	Foundation Science and English integration possibilities. Possibility of some Foundation Mathematics integration – drawing graphs, calculations, etc.
Fracture - causes and avoidance	Foundation Science and English integration possibilities.
Working with metals Hotworking and coldworking –eg annealing age and precipitation hardening strain hardening rolling, drawing and bending residual stress	Foundation Science and English integration possibilities.
Iron and Steel Introduction to steels Special steels Surface treatments Weldability Stainless steels	Foundation Science and English integration possibilities.

4.1.7. Validity with respect to the disciplines being integrated

The tasks, themes and projects being integrated must have 'validity' within each discipline, for each discipline and beyond each discipline (Jacobs, 1989). This is best illustrated by an example of an assignment that integrates, say Mathematics and EMS. An assignment using a Tensile test could be used as an example. A Tensile test is a valid test for the strength of a material within EMS; at the same time the calculation of the tensile strength has validity within Mathematics. The calculation of tensile strength is a valid part of manipulation of formulae within mathematics while the tensile test is a valid part of Strength of Materials within EMS, satisfying the second aspect of 'validity' for a discipline. When building or testing a machine or mechanism made of a material that comes under tension, the assignment on the use of the tensile test on such material has validity beyond the component

disciplines/subjects when used to answer the question: is the material strong enough for the required use of the machine or mechanism? This demonstrates a 'validity' beyond EMS and Mathematics.

The 2002 report, referred to above, identifies only one area of integration between EMS and Foundation Mathematics, namely in the mechanical tests (Table 4.3). This area where tasks would have validity within EMS and Mathematics, demonstrating 'natural affordance' (Kress, 2000) between the two, was also shown by the following statement:

Where Mathematics can be brought in is with the Tensile test, you can explain graphs as well as calculations, you can link to the broader science properties
(Lecturer EMS L03).

This is indirect confirmation that EMS would treat the concepts of Mechanics in a descriptive manner. This is supported by reference to a sample Foundation EMS test (Appendix L and M) where definitions of Mechanical Engineering concepts are being assessed in the absence of any mathematical formulae and calculations. There are also no applications of any of the engineering concepts being evaluated here. Thus the use of concepts, at a higher level, within other equivalent settings, a process necessary for conceptualisation or reconceptualisation (Sfard, 1991), would have been limited.

4.1.8. From a Fragmented Model towards a fully integrated one

Due to the above factors on 'polarity', 'affordance' and 'validity', although the model was thought of as 'fully integrated', it was more consistent with a 'fragmented model' (See section 2.5.3.). These conceptual flaws fundamentally influenced the Foundation lecturers conception of integration, which meant that they transmitted the flaws in practice. The Foundation students bore the brunt of the implemented conceptual flaws. The Foundation lecturers' conception of integration evolved, which meant departing from the original Model (see Figure 4.1, above). By the middle of 2005 the Foundation lecturers developed a conception which was closer to a 'fully integrated' one (Fogarty, 1991). The Foundation students' understanding of integration mirrored the evolution of the conceptual development of the Foundation lecturers.

4.1.9. The evolution of the Foundation Programme lecturers' conception of integration

Their initial conception of integration

The Foundation Programme lecturers of 2002 did not have a broad view of the conception of integration (Jacobs *et al*, 2002). They were reported here to have an understanding of integration as 'sequenced' (Fogarty, 1991) and referred rather to integration of Mathematics and Science rather than with EMS. Further, they were also reported as not understanding the role of language in conceptual development and of decoding the discourse practices of Mechanical Engineering.

There was only one of the Foundation lecturing staff from 2002, namely the Mathematics lecturer, who also formed part of the staff in the years 2003 to 2005. This meant most of the Foundation lecturers over the latter period did not have the benefit of having participated in a full evaluation of their teaching and learning approaches.

Their conception develops from a 'fragmented' towards a 'sequenced' approach

The Foundation lecturers of 2003 implemented an integrated project with EMS as the centre (Appendix V). This amounted to an artificial forcing together of a community project with a Tensile test (The stated outcomes were a community project and a tensile test with no link between the two). The conceptual flaw of the course designers was mirrored by the Foundation lecturers with the same features: lack of 'affordance' (Kress, 2000); 'polarity' and lack of 'validity' (Jacobs, 1989). This is also borne out by the moderator report on this integrated project (Appendix W). The integrated project for the second half of 2003, the manufacture of a collapsible washing line can be seen as an attempt to rectify the conceptual flaw of the community-tensile project. This project involved

... the manufacture from a scale drawing of a collapsible washing line, so Drawings, Manufacturing, Comm[unication] skills, Mathematics and Computer skills were included (Lecturer Main L02).

This meant that the Foundation lecturers of 2003 developed from a 'fragmented' approach towards a 'sequenced' approach (see section 2.5.3.) in the second half of the year. This would still have meant that for the Mechanics concepts in Foundation

Science, the students would have to make connections of 'equivalence' (Goodsen-Espy, 1998) on their own with regards concept formation. A 'procedural deep' approach among students would potentially be encouraged (Case & Marshall, 2004).

A sequenced approach develops but is still constrained by conceptual flaws of the original model

There was a change in staffing again in 2004 with new Foundation Science, Computer skills, Foundation Communication skills and Manufacturing lecturers. There was the same staffing for 2004 and 2005, except for the Communication skills lecturer who now taught the subject throughout the year instead of for 6 months only.

In mid-2004 the Department of Mechanical Engineering conducted an in-depth review of integrated projects, which involved tightening up on consistency in marking, setting clearer assessment criteria for students and selecting link subjects for integration (Appendices Q - U). No attention was given to a link subject for the Foundation level. This was an oversight as it meant that the Foundation level was not adequately reviewed and that flaws on 'affordance', 'polarity' and 'validity' were not addressed.

The 2004 integrated project (Appendix X) illustrated that a 'sequenced' view of integration was conceptualised. The first half of the year was for conceptualisation, design and drawing of a scale model, while the latter half of the year was assigned for the manufacture of a scale model. This was not adequate to address the conceptual shortcomings of the model of the Foundation programme. This meant that obstacles to integration were not completely eliminated. All the shortcomings of a sequenced model such as the promotion of a 'procedural deep' approach among students would have persisted (see section 2.5.3.). The same project was also used for the first half of 2005 (Appendix Z). Both projects were not linked to specific concepts in Foundation Science or Mathematics. This meant that the project was not linked to the process of concept formation or reconceptualisation in Science or Mathematics (Sfard and Linchevski, 1994). Lectures being 'sequenced' would have led to student making connections across subjects on their own of equivalence (Goodsen-Espy, 1998). 'Polarity' (Jacobs, 1989) was also evident in a disagreement among the foundation lecturers when moderating the first semester 2005 projects. A lecturer with a Mechanical Engineering background argued:

Concept formation is various concepts that are there on the market now...it costs a lot of money to design something, that is why you have to look at what the market says (Foundation 2005 L03)

The argument was opposed by lecturers without a Mechanical Engineering background, for example:

Concept formation is what ideas they are coming up with (Foundation 2005 L02).

Foundation lecturer (2005 L03) awarded a group 78% for the integrated assignment of the first half of the year, despite saying that it was the worst report he had ever seen. The discussion around this discrepancy led the Foundation lecturers to shift their conception of integration towards a more 'fully integrated' approach:

...based on student interviews and results we decided to rework the integrated project. We need to concentrate on practicals , integrate according to practicals and across concepts... some subject may not be accommodated but that is fine, please think of practicals where your subject will be (Foundation 2005 L02).

This shift was also demonstrated by the following:

Practicals should be held on certain days so this will involve co-ordination of teaching, promote team teaching, we each must carry our weight to make sure that students are properly prepared (Foundation 2005 L01).

The initial model is abandoned and steps were taken towards a 'fully integrated' approach

At the review meetings in 2005 the discussion of the assessment criteria of the concept-linked practicals involved all the Foundation lecturers. This meant that they developed or negotiated a common understanding of concepts being assessed, in advance of presenting them to students. This meant that there was a mechanism to address issues of lack of 'polarity', 'validity' and lack of 'affordance'.

The 2005 Foundation lecturing staff displayed some understanding of the role of language in accessing the discourse of Mechanical Engineering. At the session of

the joint mid year meeting of the Foundation staff (referred to above), it was decided that there be a trial run of the report of the practical so that feedback could enhance the end product. In the context of having jointly worked out the assessment criteria demonstrates an understanding of opening access to students to the discourse of Mechanical Engineering. This is further supported by the following statements on assessment criteria for an integrated practical:

The shift towards an emphasis on conceptual understanding and in-depth assessment (Sazhin, 1999) as opposed to simple recall of content knowledge, was demonstrated by the following:

Does the answer reflect an understanding of the concept? (Foundation 2005 L03).

This is further supported by the following:

...we still need to consider S1 criteria as we did with the S1 integrated project we look at integrated project report to see how well they have integrated everything they have learnt and not the individual subjects that contribute, so we basically look at end product as a whole and when we look at Communication skills we are not going to go through it with a fine toothcomb and see how bad the grammar is (Foundation 2005 L04).

An emphasis on the 'Group C' thinking skills (Smith *et al*, 1996) was also shown:

If you have made a mistake, are you able to identify the mistake and go back and see where you went wrong? (Foundation 2005 L04).

Encouragement of internal reflection of an 'equivalent' setting (Goodsen-Espy, 1998) of a theoretical calculation of a concept with a practical demonstration thereof, and thereby of 'proceptual' thinking (Gray & Tall, 1994) is demonstrated by the following:

...for the equilibrium, they will not get exactly zero; if they are able to put forward a coherent explanation of why it is not zero, this is acceptable (Foundation 2005 L02).

This development among the Foundation lecturers in mid 2005 meant that the model was changed towards a more 'fully integrated' one, as issues of 'polarity' (and 'equivalence'), 'validity' (and use of concepts at higher levels), as well as 'affordance' (and concept formation) were now being considered (see section 2.5.3.).

4.1.10. Student views on the conceptualization of integration in the Foundation Programme

The study now turns to another crucial aspect, namely how students conceptualised integration in the programme. Student understanding of integration reflected the understanding of the Foundation lecturers and were also consistent with the conceptual flaws of the Programme model.

The 2002 student cohort's understanding of horizontal integration

These students identified one of the major challenges of an integrated approach, namely that staff delivering the programme should have sufficient expertise in the subject matter (Scott, 2001):

A lecturer might say that he/she only focuses on his strengths, and may only understand his field (Student 2002 S01).

This reflects a 'fragmented' approach on the part of the Foundation lecturers who implemented the Programme.

The 2003 student cohort's understanding of horizontal integration

Aspects of a sequenced (and procedural) approach of the Foundation Programme exemplified by the following:

...[the integrated project] was supported mathematically by calculations, formulas from Foundation Science (Student 2003 S01).

This shows that there was some preparatory work in FM and FS prior to integrated assignments.

A fragmented curriculum approach (and lack of concept formation), however was still an important factor:

The Foundation course has one weakness and that it only deals with theory and almost no technical work that will allow you to think all the time. You are

not getting any work into your brain...we cannot apply what we have learnt (Student 2003 S01).

Students realised that the lack of use of concepts in 'equivalent' forms (Goodsen-Espy, 1998) and at higher levels (Sfard, 1991), would hinder their cognition thereof.

Students also understood, based on their experience of mainstream study, that a lack of conceptual understanding would have dire consequences:

There should be more integration because most students struggle with Foundation Science... If Mechanics was integrated to Maths more, you would get a clearer picture, because if you fail Mechanics the first time you would be likely to fail again or struggle always (Student 2003 S02).

This is also indirect confirmation of a lack of sufficient integration at Foundation level.

Foundation EMS did not appear to play a role to support the understanding of Mechanics concepts, further evidence of a 'fragmented' approach:

Material science should be moved into the second semester so that the year is more balanced ... show us how things work, we will have a clearer understanding... (Student 2003 S03).

For students to propose that EMS be shifted to the second semester shows that its role in supporting Mechanics concepts was tenuous. Students' call for showing 'how things work' also points to a lack of sufficient integration of Foundation Mathematics into Foundation Science. This is consistent with the conceptual flaws in the Model outlined above, resulting in a 'fragmented' approach.

The 2004 student cohort's understanding of horizontal integration

Evidence of a 'sequenced' integrated (and 'procedural') approach is demonstrated by the following:

I think that Foundation Maths played a big role even in Foundation Science. It played a big role in S1 Mechanics and Maths 1. For example if you go into equations some of already knew and others learnt how to make equations (Student 2004 S01).

This also points to a direct support of Foundation Mathematics to Foundation Science, to Mechanics and to S1 Mathematics, not via EMS.

That the approach was 'procedural' and did not take into account of 'polarity' (Jacobs, 1989) is evidenced by the following statement:

[for the integrated project] you had to put in every subject (Student 2004 S03).

The 'procedural' approach was reflected by students understanding of integration as the 'forcible' use of all subjects in the assignment, irrespective of what the assignment was about.

That there was not sufficient sequencing of integration to give adequate time for the process of concept formation (Sfard & Linchevski, 1994) in Mechanics is demonstrated by the following:

I think it would be wise for them to be introduced to such chapters way before the time... Most people don't understand Forces, and if they were introduced to it earlier, they'll pass (Student 2004 S03).

Based on their experience of mainstream study, students realised the value of integration providing concepts in 'equivalent' forms (Goodsen-Espy, 1998) in different subjects which would deepen their understanding:

the basics of Mechanics and of S1 Maths must be covered at foundation...[there must be more integration] because if subjects interlink with each other it is more easy to understand (Student 2004 S04).

Therefore the 2004 cohort also, by implication challenge EMS as the core subject for supporting cognition of Mechanics concepts.

The 2005 student cohort's understanding of horizontal integration

'Full integration' and the interconnectedness of subjects is shown for the first time in this cohort.

Without knowing the theory behind 'metacognition' students realised that learning of concepts was a process:

It actually puts you through a better understanding when you do integration project and chalk on the board (Student 2005 S03).

The role of Mathematics in understanding 'equivalent' forms (Goodsen-Espy, 1998) in Science, a proceptual understanding (Sfard, 1991; Gray & Tall, 1994) – the process in Mathematics linked with a concept in Science- was understood by students:

It's like Maths is the language of Science, you can't do without the Maths (Student 2005 S06).

That there was still room for improvement is demonstrated by:

We should have more practicals on Vectors and Geometry as it is difficult to find what angle is what (Student 2005 S03).

That students had very little experience of integration before the Foundation course is exemplified by the following:

There wasn't integration at high school between Maths and Science (Student 2005 S03).

Summary of the main findings of student understanding of horizontal integration

- The 2002 cohort identified an important challenge for integration, namely that integration needs appropriately trained staff; in the absence of this, as happened to them, a fragmented approach could result;
- Although the 2003 cohort provided some evidence that a 'sequencing' approach to integration had been used, the lack of practicals provided evidence of a 'fragmented' approach. The students understood that the lack of use of concepts in 'equivalent' forms, at higher levels, would hinder their cognition of Mechanics concepts;

- The 2004 had a 'procedural' approach to integration (understanding that all subjects had to be used in integrated assignments), although some evidence of 'sequencing' was provided by them. Nevertheless, students understood that adequate time was needed in 'sequencing' of learning for cognition of concepts to occur;
- Whereas the other cohorts spoke of steps towards a 'fully integrated' approach, only the 2005 cohort spoke from having experienced it. They realised that learning is a process; that the process of Mathematics is a key to understanding in science, in other words, they showed evidence of realising the importance of 'procepts' (Gray & Tall, 1994) and the role of integration in providing opportunities for cognition based on this.

Among the 4 cohorts the 2005 one appears to have the clearest understanding of 'full integration'. This supports the evidence of the Foundation lecturers in 2005 having a clearer conceptual understanding of integration than the lecturers in 2002. The evidence suggests an association between the conceptual understanding of integration by the students and the understanding by the Foundation lecturers. The evidence also suggests that the conceptual understanding of the lecturers on integration preceded the conceptual understanding of the students on integration (the Foundation lecturers set up the integrated assignments before the time and then implemented them). This is the first step towards establishing a causal relationship between the conceptual understanding of integration by the lecturers and the students.

It is noteworthy that not a single student cohort, not any other student interview or view from any student questionnaire hinted at or mentioned a link between understanding mechanics concepts through integration with EMS. This is further evidence of the conceptual flaw of the Foundation programme designers.

Lastly, the vertical integration of Foundation Mathematics with S1 Mathematics is shown by the following:

There is a part of Maths that has to be on its own, that can't be integrated with Science (Student 2005 S02).

This leads directly to the next subsection which deals with the other conceptual aspect of the Foundation Mathematics course, namely vertical integration with S1 Mathematics.

4.1.11. Vertical Integration of the Foundation Mathematics course into S1 Mathematics

The FM course was conceptualised as preparing students for S1 Mathematics, that is, vertical integration (Jacobs *et al*, 2002; Appendices E, F & G). On the basis of the FM results for 2002, the evaluation survey concluded that vertical integration had been successful. This was premature as there had been no causal relationship established between FM and S1 Mathematics. Even though it is not a direct aim of this case study to examine in detail the relationship of FM to S1 Mathematics, it has to discuss this. S1 Mathematics is itself a subject which supports Mechanics 1 as well as laying the basis for further Mathematical support to Mechanics-related subjects at higher levels.

The emphasis of the FM course designers was on students gaining 'structural awareness' (Cifarelli, 1988) of basic mathematical concepts and of them developing 'proceptual' ability or being able to understand 'process-object duality' (Sfard, 1991; Gray & Tall, 1994). This is borne out by the following quotation:

If students know Mathematics on a purely analytical basis then applications comes naturally (Lecturer Maths L01).

The FM course designers could thus be seen as having a 'connected' approach (see section 2.5.3. p25) to vertical integration, with their focus on assimilation of ideas within the realm of 'pure' Mathematics.

They also felt that there should be a judicious approach of the use of practicals to guard against a 'procedural' (Case & Marshall, 2004) approach developing:

A practical approach can be used but once a concept is grasped it is important to immediately bring in abstraction, otherwise students will always rely on practical Maths. Maths is more powerful if students can abstract; they sometimes learn the rules but do not understand what is going on (Lecturer Maths L02).

The FM course designers felt that a focus on practicals could lead to students concentrating on the procedures of the practicals rather than concepts being demonstrated.

There was a different conception of the FM course held by the course lecturer, whose approach, with its emphasis on content and thinking skills, could be described as a 'nested' integration (see section 2.5.3.). This is exemplified by the use of questions in evaluations (Appendices F1, G1, G2) in 2004 and 2005 that were more based on 'recognition' or 're-presentation' (Cifarelli, 1998), or on 'interiorisation' or 'condensation' (Sfard & Linchevski, 1994). Question 3 of Appendix G2, on the calculation of the area cut off from a circle to form a hexagonal shape, could have been solved through abstracting and application of the segmental area formula but could also have been solved with lesser routine arithmetic and geometric procedures. Except for this question, very few of the questions required the use of 'Group C' (Smith *et al*, 1996) thinking skills (such as involving justifying, conjecture, comparison and evaluating). The result of this approach would have encouraged at worst a 'procedural surface' or at best a 'procedural deep' approach. In 2002 and 2003 the second half of the year (See Appendix H) involved teaching differential and integral calculus as part of the Foundation year, which would have ensured that elements of 'structural abstraction' and 'structural awareness' (Cifarelli, 1988) would have had to be developed. (For example, through the use of the definition of a derivative from first principles to the use of the derivative without reference to first principles).

In 2004 the S1 Mathematics was removed from the Foundation year (Appendix F), which would have meant that a 'procedural' approach of the lecturer would have dominated.

In 2005, with the inclusion of complex numbers in the FM course (Appendix G), elements of 'structural abstraction' would have been included in the course. (Complex numbers include numbers which are beyond the set of real numbers – this means that 'structural abstraction' is inherent in the understanding of Complex numbers).

The change in the FM course to a full year one meant that whereas the cohorts of 2002 and 2003 were taught S1 Mathematics in a Foundation class, the cohorts of 2004 and 2005 were taught S1 Mathematics while in bigger classes together with the usual first year student intake in the Department.

The 2002 student cohort's understanding of vertical integration of FM

The 2002 student cohort demonstrated characteristics of reaching a 'condensation' stage of understanding of mathematical concepts:

...you have to understand Maths to understand formulas (Student 2002 S02).

They could understand a complicated process such as a formula, but their understanding was still tied to the algorithmic process associated with it.

Evidence of vertical support of Mechanics, not via EMS, is shown by:

Good preparation for S1 especially Maths and Mechanics. A lot of it [FM] is the same as Mechanics one (Student 2002 S02).

The evidence presented in previous sections shows there was little support for Mechanics concepts through integration with EMS at Foundation level. The above evidence, that FM prepared students for Mechanics 1, points to a possible 'polarity' between the needs of preparation for S1 Mathematics (mainly based on calculus) and the need to support the mathematical needs of Mechanics 1 (mainly based on pre-calculus Mathematics).

The 2003 student cohort's understanding of vertical integration of FM

Although they did not use terms like 'metacognition' (Schoenfeld, 1999) or 'interpretation' skills (Smith *et al*, 1996), students recognised these as important aspects of Mathematics learning:

In Maths we always taught that there's not only one way to solve a problem. It does not have to be the same procedure, do what you think you know (Student 2003 S04).

This is consistent with a 'nested' approach where thinking skills are also taught. It also reflects a 'procedural' understanding of interpretation on the part of these students as they limit themselves to 'do what you think you know'.

Further evidence of a 'surface approach' by these students, due to a concentration on examinations, was also shown:

I would recommend (the FM course)... Every time I write exams I rush, I realised afterwards I make mistakes. So the FM course made me realise I don't need to rush (Student 2003 S02).

The student felt confident enough to recommend the FM course because it gave better preparation for examinations rather than improved their conceptual understanding of Mathematics- further evidence of a 'procedural' approach.

The 2004 student cohort's understanding of vertical integration of FM

The 2004 student cohort's understanding of vertical integration was that the FM course also gave some support to Mechanics but not via EMS:

Maths helped me a lot to do Mechanics but it was a small job. The semester courses are now more work than a year course (Student 2004 S03).

This also reflects the Pre-Calculus emphasis of the FM course (see Appendices F & F1; Table 4.3). The absence of use of the basic concepts at a higher level, such as calculus, could have weakened student mathematical concept formation (Sfard, 1991).

This cohort also exhibited characteristics of a 'procedural' approach:

In S1 with graphs, we were already exposed to graphs... If you did not meet your aim you will lose marks...in industry you will lose a job or something (Student 2004 S01).

Once again students related knowledge of mathematical content to examinations rather than conceptual understanding.

The 2005 student cohort's understanding of vertical integration of FM

The 2005 student cohort also exhibited characteristics of a 'procedural' approach:

When doing calculations everything afterwards you'll find out your answers don't match with the mathematical method and science method, so you must use Maths (Student 2005 S06).

They mechanically contrasted the use of different methods rather than understanding of concepts. This is consistent with a 'nested' approach where students may be confused and lose sight of the main concepts of the lesson or activity.

This is further supported by the following:

To work out the answer we use maths to work out percentage error (Student 2005 S01).

The student had lost sight of the calculation of an answer within an acceptable range of accuracy and focuses on the mathematical procedure to calculate the percentage error.

Summary of findings of vertical integration of the FM course

There was 'polarity' of conceptual approach to integration of the FM course between the course designers and the lecturer. The FM course designers adopted a 'connected' approach while the lecturer adopted a 'nested' approach. The 'nested' approach with its emphasis on deconstruction rather than use of concepts at higher levels (see section 2.5.3.) would have led to a more 'procedural' understanding of Mathematics. All the student cohorts that were part of the study demonstrated 'procedural' approaches that were consistent with a 'nested' integration approach.

Further evidence was presented by the students, of support for Mechanics concepts from the FM course and not via the EMS course.

The need for 'structural abstraction' and 'structural awareness' (Cifarelli, 1988) in the Foundation year would appear to have been partially met with the inclusion of S1 Mathematics in the 2002 and 2003 programme, while it would have been met to some extent with the inclusion of complex numbers within the FM outcomes in 2005 (Appendix G) but in 2004, in its absence, a 'procedural' approach could dominate.

'Polarity' (Jacobs, 1989) of meeting the needs of support for Mechanics 1 (see Table 4.4) and meeting the needs of 'abstraction' (Cifarelli, 1988) for S1 Mathematics would have undermined vertical integration of FM with higher levels of Engineering Mathematics. Mechanics 1 was based on Pre-Calculus Mathematics (Fawkes, 1999).

This means that although integration of Mathematics into Mechanics may bolster Mechanics performance, the impact on Mathematics may not be as far-reaching.

Table 4.4. Mathematical techniques required in Mechanics 1

Mechanics: Course outline	Common concepts and skills in Mathematics
Conversion of units	Measurement; dimensional analysis; accuracy; exponential notation
Forces	Vectors; trigonometry;
Moments	Manipulation of formulae; trigonometry; vectors
Gases	Relations; construction of formulae; graphs of different relations; manipulation of formulae
Atomic structure	Balancing of equations; conversion from mol to g and vice versa
Centre of gravity	Areas; volumes; co-ordinate geometry
Friction	Proportion; trigonometry; vectors
Internal forces	Vectors; trigonometry
Rectilinear motion	Manipulation of formulae; graphs; velocity; acceleration; displacement
Angular motion	Angular displacement; radian measure; angular velocity; angular acceleration; ratios ; proportion; relations
Centripetal force and acceleration	Angular displacement; radian measure; angular velocity; angular acceleration; ratios ; proportion; relations; vectors, trigonometry
Work Energy, power	Manipulation of formulae; vectors; trigonometry
Momentum; impulse	Manipulation of formulae; vectors; trigonometry
Lifting machines	Ratios; relations; manipulation of formulae; graphs

4.1.12. Limiting opportunities for concept formation

The limited opportunities for integration of EMS with Foundation Mathematics also limited the opportunities for students to reconceptualise their ideas on the concepts of mechanics, and other basic concepts. Opportunities were limited for students to refine their schemata /intuition on the mechanics concepts from a verbal description only, that is without examining the mathematical process underlying it (Fuchsbein, 1999). Thus opportunities seeing and practising process- object duality, necessary for concept formation, were limited (Sfard, 1991; Gray & Tall, 1994). The scope for

Group C thinking skills and thus the scope of deeper learning were limited (Cifarelli, 1988; Sfard & Linchevski, 1994; Smith *et al*, 1996).

4.1.13. Extending Language support

The conceptual flaws in the model of integration (Figure 4.1) where the function of Literacy (through the Foundation Communication Skills course) was to support EMS, limited the support for Mathematics and Science.

The earlier evaluation (Jacobs *et al*, 2002) suggested that there be greater integration of Language into Foundation Mathematics and Foundation Science. However, a survey of the Communications Skills Course outlines (see Appendix JJ) yielded scant evidence of this. Two chapters (Units 2 & 3) in the Foundation Mathematics book (Cloete & Mahomed, 2002) had summaries translated from English into Afrikaans and isiXhosa. The value of such translations are as yet, untested.

Despite the conceptual flaws in the Foundation model, the Communications skills course did assist students in developing tertiary academic skills:

We learnt in Foundation that even if you don't understand a word try to understand the sentence context and figure out what the meaning of the whole sentence is (Student 2003, S02).

This implied that even though mathematical concepts were not directly supported by the Literacy component, students would have benefited from the reading skills gained from it.

There was 'polarity' between the needs of Literacy and the needs of other Foundation courses:

[not having English as a first language did impact on us] in Foundation language we had to meet certain criteria, but not in other subjects (Student 2004 S01).

The different requirements of Literacy (Foundation Language) posed a possible point of 'polarity' within integrated assignments.

From 2002 to 2004 Foundation Communications skills did not support FM or FS:

Yes, Maths and Science terms should be explained in Communications [Skills] as more technical language will also improve ((Student 2004 S02).

Further, the need for English support as part of the Foundation Programme is supported by the following:

In high school we are used to being taught in Xhosa. Even if he taught Maths he used Xhosa. English is like wow, you are not used to it (Student 2004 S01).

Preparations for the second phase of the Foundation programme, which does not include EMS, has yielded plans for literacy support to all S1 subjects, including Mathematics (Appendix FF). This suggests that direct integration of Foundation Mathematics with concepts in Mechanical Engineering, not via an artificial construct (EMS), offers greater opportunity for the decoding of the discourse practices of Mechanical Engineering.

Summarise the main findings on Language support

- Language support was part of the original Foundation model
- Foundation Communication skills did aim to improve student tertiary academic skills
- There was limited support from Communications skills for FM and FS during the period of this case study as the model focused on English support for EMS
- Students still regard English support as necessary, especially if they are not first language English speakers
- There was 'polarity' between the needs of Communications skills and the needs of other Foundation subjects

Having discussed the Conceptual model within which the Foundation Mathematics course is located, it is opportune to turn to a discussion of the Design aspects of this model.

4.2. The Design of the Mechanical Engineering Foundation Programme

Whereas the discussion on the conception deals with the model of the Foundation programme, the discussion of the Design phase examines the plan for the implementation of this model.

In this section are presented the research findings on the design of integration in the Mechanical Engineering Foundation Programme, with reference to Foundation Mathematics.

4.2.0 Introduction

The Foundation EMS course was designed to start from basic concepts in Mechanics, Thermodynamics, Fluid Dynamics, etc, to progress to properties of materials with associated materials testing, culminating in an in-depth study of stainless steels (Jacobs *et al*, 2002).

There was supposed to be 6 hours per week of support to EMS from Communication skills (Language), while support from Foundation Mathematics and Foundation Science was each designed to give 3 hours of support to EMS. Foundation Mathematics and Foundation Science each had 2 hours per week for vertical integration with their respective S1 subjects (Table 4.1). This appears to contradict the claim made by Jacobs *et al* (2002) that the main objective of Foundation Mathematics was preparation of students for S1 Mathematics.

The conceptual flaws would necessarily have led to design flaws as well. Against this backdrop the design flaws of integration are examined below.

4.2.1 Design flaws with respect to integration of Language (Foundation Communication skills)

The assumption was made that most if not all of the students would be second language English speakers. An English-based Foundation Communications skills course was part of the designed programme. Again, a design flaw emerges, the Communications skills course was designed to 'horizontally' support EMS and not the concepts that students had most difficulty with, namely, Mechanics. Foundation Communications Skills supported the materials content and not Mechanics concepts that may have nominally been in the Foundation EMS course (Appendix FF). It was

assumed that language support for EMS was a sufficient basis for an introduction to the field of Mechanical Engineering.

The module on stainless steel occurred first in the Foundation Communications skills course, whereas it was the culmination of the EMS course (Jacobs *et al*, 2002). The other modules of Communication skills were also out of sync with the EMS course. The section on integrated projects was the last module in the Communications skills course. This was also out of sync with the EMS (and other courses), and did not support any attempts at integration. Despite the recommendations of the 2002 evaluation (Jacobs *et al*), the Communications skills course remained unchanged for 2003 and largely the same for 2004.

Students had not been given a background to stainless steel in EMS by the time the Foundation Communications skills course introduced this topic. No support was given to student cognition on stainless steel and confusion resulted:

...the students did not know what we were talking about [in 2003] when we introduced the first module on stainless steel (Lecturer 2005 FL04).

This shows that the design of the Foundation Communications Skills course did not support concept formation in EMS.

The Foundation Communications Skills course also did not support concept formation of Mechanics nor of Mathematics:

The main weakness is in the language, yes the activities we did were related to our materials and science (EMS) which I think is not good (Student 2004 S03)

This demonstrates that students felt that the Foundation Communications Skills course did not give them support in areas that they needed assistance.

In 2004 the Foundation Communications Skills lecturer wrote a new section on report writing which was presented in the first half of the course (Lecturer 2005 FL04). This would have supported integration in the Foundation programme with any of the other subject areas. In 2005 a revised course book was presented with the module on stainless steel still in the first part of the course but at least 'materials testing' was

shifted to the latter half of the course (Lecturer 2005 FL04). By 2005, however, the EMS course had been dropped from the compulsory offerings for the mainstream Mechanical Engineering programme and thus also from the Foundation programme. The EMS lecturer of 2003 and 2004, had apparently collaborated on the 2005 new Communications skills text, but the integrated project module was still at the end of the course. There was no input from the Foundation Mathematics, Foundation Science or other Foundation subject lecturers into the new 2005 Communications skills book (Lecturer 2005 FL04). This consultation only with the EMS lecturer can be seen as stemming from the conceptual flaw of choosing EMS as the 'core' for the Foundation programme as a whole.

The 2005 Foundation Communications skills design was closer than that of 2004 to that of a 'shared' (see section 2.5.3.) integrated programme, including broad contextualised reading and comprehension aspects (Appendix JJ). Support for Mathematics and Science was still absent. The impact of the midyear discussions in 2005 and the change in design to support all subjects and thus take steps towards a fully integrated programme is evident from a plan to revise the Communication Skills course material (Appendix FF).

Several opportunities, however, were lost for Foundation Communications skills to effectively assist in the decoding of the discourse of Mechanical Engineering and raises challenges design to assist towards the creation of a fully integrated programme.

The need to change the design of the Communications skills course to be more vertically integrated is highlighted by the following:

'there are various aspects of report writing from S1 that are not covered in Foundation Communication skills, this is a worry (Lecturer 2005 FL04).

This is further supported by the students:

The weakness in the course is that we are not do [sic] everything in Communication skill at S1 level (Student 2003 S04).

The change in 2007 to a new extended Foundation programme, where the S1 subjects are extended from 6 months to 1 year, reinforces the need to re-curriculate

Foundation Communications skills. In the words of the Foundation Communications skills lecturer:

We need to prepare a new Extended Curriculum Foundation skills text (Lecturer 2005 FL04).

4.2.2 English competence and English Support

All students on the Foundation Programme were required to do a Communications Skills course. Forcing students who are competent English speakers to do a Foundation Communication skills course creates what Jacobs *et al* (2002) describe as an 'internal design flaw'. This is supported by the following:

The weakness is that if you are in [*sic*] foundation course you also have to do Foundation Drawing and also F Language instead of doing Maths [*sic*] Foundation, because some of us only failed maths (Student 2003 S02).

That the question is far from simple can be seen from the following quote:

I personally resieved [*sic*] 65% in English so why should I do Foundation English. It's a waist [*sic*] of my time and your money (Student 2003 S05).

It is notable that the student cohorts of 2004 and 2005 did not raise similar concerns, despite also being asked the same question for suggestions to improve the course. Whether to exclude English competent students from English support should be subject for further research. If such students are excluded this would mean them missing out on an opportunity for support in decoding the discourse of Mechanical Engineering. The design objective of the Communications skills course go beyond the raising of English competency of the students and including reading and understanding engineering texts (Appendix JJ). There are also opportunities to use the English competent students as tutors to assist the less competent ones.

4.2.3. Integration with Foundation Science

In sections 4.1.4 to 4.1.7. it was explained that EMS was inappropriately conceptualised as a 'core' subject. It is expected that design flaws would result from this lack of conceptual clarity. From a comparison of the course outline of Foundation Science of 2002 (Appendix E) and Table 4.1 , it is evident that all the topics in Foundation Science could be found in the EMS course under the heading of

Mechanical Engineering concepts. With EMS being the focus for integration of the Mechanical Engineering concepts, the opportunity for supporting conceptual development (Sfard & Linchevski, 1994) was lost because there was no plan for direct integration of Foundation Mathematics with Foundation Science. The Foundation EMS lecturer of 2003 and 2004 said:

I covered the whole of Thermodynamics, Mechanics, Fluid Mechanics, and other basics of Mechanical Engineering in 2 weeks, the rest of the time [13 weeks], I spent on the Science of Materials (Lecturer EMS L03).

To design 3 hours weekly, each, of support from Foundation Mathematics and Foundation Science into EMS, was a serious 'internal design flaw'. The integration of Foundation Mathematics into Foundation Science was left open to chance and was not supported by the design.

4.2.4. Validity in each subject or discipline

The thinking skills required for Foundation Science (FS) were more Group B and C, requiring justifying and interpreting, for example (Smith *et al*, 1996; Fawkes, 1999). Each of the concepts in FS could be linked to a combination of mathematical processes (see Table 4.4) and thus lent itself to not only to 'process- object duality' (proceptual thinking) but also offered the possibility of use of mathematical processes in equivalent forms at higher levels within Foundation Science contexts (Sfard, 1991; Gray & Tall, 1994). Integration of Mathematics into Science therefore lends itself to concept formation (Sfard & Linchevski, 1994). The scope for integration of concepts having 'validity' in EMS as well as Mathematics and Mechanics was thus very limited. The role of Foundation Communications skills was thus also limited as it supported understanding of terms that were metallurgical and thus limited in their proceptual scope, on the one hand, while giving no support to proceptual terms in common usage in Mechanics and/or Mathematics. In fact, six hours per week of support to the Mathematics and 'Physics' concepts in EMS were supposed to be given – a serious design flaw as the content and thinking skills required were so divergent.

Further, the nature of the EMS course, being based on the simple recall of a huge amount of facts (see Appendices K, L & M), lent itself to 'surface' learning (Group A) or 'procedural' thinking, while the opportunities for deep learning (Group B and C) were limited (Smith *et al*, 1996). The absence of mathematical formulae in context

meant that opportunities for bridging the 'proceptual divide' were just not there (Gray & Tall, 1994).

A valid integration of EMS with Foundation Science would have been molecular structure, which occurred in both subjects. Molecular structure however has a tenuous link with Foundation Mathematics. (see Appendix E). In the absence of 'sequencing' (reported on in Jacobs *et al*, 2002), attempts at integration of EMS with Foundation Science and Foundation Mathematics could only have contributed to a 'potpourri effect' (Jacobs, 1989). Jacobs *et al* (2002) reported on this confusion in the minds of the lecturers as well as the students when stainless steel was tackled first in the Foundation Communications skills course but last in the Foundation EMS course. The EMS lecturer expected the Communication skills lecturer to cover the section on stainless steel while the Communications skills lecturer did not feel equipped to explain the section on stainless steel.

As Foundation EMS was to be the main core where Foundation Mathematics would be integrated to support Mechanics concepts, the overall conceptualization and design of the Foundation programme was thus an obstacle to integration of Foundation Mathematics with Foundation Science. (Foundation Science was mainly based on Mechanics concepts- Appendix E).

4.2.5. Horizontal integration of Foundation Mathematics

The study now turns to the plan for support of the Foundation Mathematics (FM) course for other subjects at Foundation level (horizontal integration).

There was a limited opportunity to integrate FM with EMS. (Jacobs *et al*, 2002). This is supported by Table 4.3 where only one topic was identified as suitable for integration of EMS with FM. This is further supported by the Foundation EMS lecturer of 2003 and 2004 who noted the Tensile test as an important opportunity for integration. This test involves analysis of graphs and algebraic manipulation of simple engineering formulae. The design of the FM course did not offer further opportunities for contextualized learning of Engineering Mathematics. This was another 'internal design flaw'. It was not clarified which sections would support Foundation Science even though some sections would (see Table 4.4). This point may be extended that there was no clarity in the course outlines (Appendices E-G) as to how FM would support other subjects taken at Foundation level. This is evidence of a 'fragmented'

approach to integration (see section 2.5.3). Evidence shows that FM course outlines were prepared at the start of each of the years 2002-2005.

The mid year Foundation planning session in 2005 that reviewed the approach to integration was the first time over the period under study that a systematic attempt was made to synchronise mathematics with ongoing concept formation in Foundation Science and other subjects.

This is shown by the following:

Practicals will be held on certain days so this will involve co-ordination of teaching...breaking up forces into components as well as adding up of the algebraic components as well as even doing a sketch, the second part involves moments, did you get to moments? (Lecturer 2005 FL02).

This demonstrated awareness among the Foundation Lecturers to ensure that the necessary aspects needed for integration had been covered, enabling integration to support cognition of a specific concept or concepts.

Prior to this, the evidence is that this horizontal support took place on an *ad hoc* basis (see Appendices V, W, X & Z).

Clarity on the sequencing and content of the horizontal integration in the Foundation year is one of the design challenges facing the lecturers.

4.2.6. Equivalence of the Foundation Programme courses with those of the mainstream

The Foundation EMS course was designed to include the outcomes of the mainstream EMS course (Jacobs *et al*, 2002). The Foundation EMS lecturer was criticized for having a 'too literal' an understanding of equivalence with the mainstream EMS course as the same assessments were set, and were conducted at the same time. Despite the recommendation of the 2002 report, the 'literal equivalence' was maintained for 2003 and 2004:

I made sure that the mainstream and Foundation wrote the same assessments at the same time. I pushed them hard and played the one group against the other, to motivate them...Looking back I can see that it was wrong

to do so. We should have had a different approach with the Foundation students (Lecturer EMS L03)

Even though EMS is no longer a compulsory offering, lecturer EMS L03 still felt strongly that a way be found for implementing simple practicals to demonstrate the concepts of Mechanical Engineering to the Foundation students.

Show a student a concept, and they remember it for life (lecturer EMS L03).

This supports the conception of the Foundation lecturers of 2005 who revised their approach to integration towards teaching towards concepts. This is further supported by the pleas of all the student cohorts for more practicals and in particular by the positive affirmation of the 2005 cohort to the brief period of teaching towards concepts.

This points to a design challenge for the course designers to re-engineer the Foundation programme on a basis that maintains the integrity of each of the Foundation courses while sequencing and co-ordinating teaching so that understanding of Mechanical Engineering concepts is promoted.

Evidence supports the re-engineering of the Foundation courses to include more substantial S1 outcomes in the Foundation year:

we should have had Mechanics in the second semester (Student 2002 S02).

This is further supported by:

The [*sic*] should be a change in Foundation Science to Foundation Mechanics. If you did Foundation during 1st semester, you should do the major subject in the following semester to keep the momentum (Student 2003 S06).

The above two quotations reflect the design flaw of having Foundation Science in the first semester of the Foundation year and only 6 months later would the students be able to take Mechanics 1.

The Programme designers responded by extending Foundation Science to a year course in 2004 and 2005. This involved more intensive examples but not more Mechanics outcomes. This was not an adequate response:

the basics of Mechanics and of S1 Maths must be covered at foundation (Student 2004 S04).

Students still felt that the basics of Mechanics and S1 Mathematics covered at Foundation level were insufficient. This was further supported by:

The (Foundation Programme) can be more challenging by adding more S1 subjects... more Mechanics terminology must be used (Student 2005 S06).

There were similar complaints by students and lecturers over the short time (one semester) for EMS, Mathematics and Communication skills. The above suggests that the response of merely extending FM, Foundation Drawings and Foundation Communication Skills to one year, as a pre-cursor to their respective S1 subjects, may not have been adequate.

The above evidence then supports the design of an extended curriculum Foundation Programme which includes all S1 subjects, but extended over one year. This is consistent with the theoretical position that the use of concepts at higher levels is needed for concept formation (Sfard, 1991).

4.2.6 Equivalence in assessment practices

Developing common outcomes with mainstream subjects like EMS, would help counter the negative effects of a 'literal equivalence' (Jacobs *et al*, 2002). (Only 49% of Foundation students in 2002 passed EMS and the EMS lecturer indicated that he was constrained by having to have the Foundation students write the same assessments at the same time as the mainstream students). Lecturers could then be freed to develop assessments and teaching methods more suited to the developmental needs of the Foundation students. They suggest common moderators for the mainstream and Foundation courses as a mechanism to assist in achieving 'equivalence'. The lecturer of EMS for 2003 and 2004 reported that both the Foundation EMS and mainstream EMS had the same moderator but that he did not use that to full effect. He had not been aware of the 2002 report of Jacobs *et al*.

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The point of common moderators for mainstream and Foundation courses that are linked, is not negated. In FM, steps towards 'equivalence' was achieved through having higher level Mathematics lecturers moderate the course (Appendices F & G). The FM course was not intended to be equivalent to S1 Mathematics but was intended to be a Pre-Calculus course (see Appendices E to G, the FM outcomes, with Appendix H, the S1 Mathematics outcomes). The suggestion for common moderators also has importance and validity with the 2007 Foundation programme where the S1 subjects are extended over one year. Foundation lecturers should not limit themselves to the rigid assignment deadlines of the mainstream courses.

This is also supported by the mid year review of the Foundation lecturers in 2005, referred to above, which suggests that in addition to moderators from the mainstream, joint moderation involving all Foundation lecturers of all integrated practicals and assignments should be central to establish a minimum level of 'equivalence' (Goodsen-Espy, 1998) for concept formation (Sfard & Linchevski, 1994) throughout the year.

4.2.7 Vertical integration

By Vertical integration of FM is meant preparation for and support for S1 Mathematics and other Mathematics-related S1 and higher courses.

An analysis of the course outlines in Foundation Mathematics from 2002 to 2005 (Appendices E-G), reveal that it is explicitly stated that one of the objectives is to prepare students for S1 Mathematics. This is evidence of design objective for vertical integration of Foundation Mathematics with S1 Mathematics.

The original 2002 model (Figure 4.1) did not include S1 Mathematics in the second semester of the Foundation year. S1 Mathematics was included in 2002 and 2003, with 2004 and 2005 having full year courses of Foundation Mathematics (Appendices F, G & H). It was only in 2005 that the FM course outline made reference to meeting the outcomes required for technologists, the CCFO's (Appendix G).

The conceptual objectives of higher abstraction and of 'process-object' ('proceptual') ability is contradicted by the design of the course designers:

Students don't know the basics, you must consolidate the basics by drilling it into them (Lecturer Maths L01).

The plan of the FM course designers promoted 'procedural' thinking. This is further supported by the following:

Students don't understand the basics, it is important to unpack the concepts even if you have to go back to primary school level (Lecturer Maths L02).

The practice of 'drilling' runs the risk of encouraging a 'procedural' approach while unpacking of concepts has the effect of deconstructing, instead of use at a higher level, with the same result (a 'procedural' approach). The design of the FM course thus was more consistent with a 'nested' approach. While the process of concept formation is recognised by the Mathematics course designers, their route goes counter to their intended results. This is further evidenced by the following:

Try as we might with getting students to unlearn errors and to learn new concepts; put them under pressure and they make the same mistakes; it's as if these errors are part of their mathematical soul (Lecturer Maths L02).

This shows that intention of encouraging student conceptual cognition in mathematics is one thing, but achieving it has to be matched by a suitable design.

A new approach is clearly needed. A challenge is finding a mechanism to accommodate the demands of a pre-Calculus course such as Mechanics 1, with the abstract demands of Engineering Mathematics.

An evaluation of a first year tertiary programme would be incomplete without an investigation of the broader issues that entry level students face. The Study turns to this question briefly.

4.2.8 Affective matters

One of the strengths of the Department of Mechanical Engineering is having mechanisms to regularly get feedback from staff and students on problem areas and on techniques that may be working well. Evidence of this is provided by the following: The 2002 evaluation of the Foundation course (Jacobs *et al*, 2002); regular student questionnaires such as Appendices B & C; reviews of the department integrated projects which included the Foundation level (Appendices P to U); moderation of integrated assignments such as Appendix W; Annual 'at risk' assessments of

Foundation students (Annexure MM). There was also a mechanism in place to respond to student academic and affective issues. The very choice of a fully integrated model for the Foundation Programme is evidence of steps taken to address issues of student confidence, student learning and related matters (see Chapter 2, section 2.5.6).

Students from the cohort of 2002 felt a sense of alienation because of their separation from the mainstream students (Jacobs *et al*, 2002). This is exemplified by the following:

The foundation students they must really be made to feel that they are part of this Mechanical Engineering. No to say that they are half students of the department... I think it is high time they introduce life skills course or anything that will assist foundation with management of time, school work, social life (Student 2002 S06).

After the evaluation (Jacobs *et al*, 2002) the department took steps to address student and Foundation staff concerns:

Every effort was made to include Foundation students as part of all the department activities such as awards ceremonies, registrations, the student chapter, the women in engineering activities. We even took on the admin to ensure that they received student loans like any other mainstream student. We tried our best to make sure that all Foundation staff were also involved in our meetings. This was difficult in the beginning as they were paid per hour but later on they were put on contract and this improved (Lecturer Main L02).

Life skills, which included time management, study skills, personal development skills, was introduced to the Foundation students informally since 2004 and in 2006 the department ran joint assignments with them in Communications skills (Lecturer 2005 FL04).

The students in 2006 even received certificates in personal development; they were so proud (lecturer 2005 FL04).

Students from the 2003 cohort spoke of the need for lecturers to develop more strategies to boost student self confidence, the need to help students cope more with

academic pressure , the question of time management and study skills. This cohort spoke of the value of team building exercise in building their confidence, such as the camp that they had been on and called for more of this. Student cohorts from 2004 and 2005 also spoke well of the camp in their respective years.

I would like a break away the same time of year with lecturers communicating with students (Student 2003 S04).

The Design of the Foundation Programme included a mechanism for affective and academic concerns to be raised within the Department and for them to be discussed.

4.3. Summary of the findings on the conceptualisation and design of the Foundation Mathematics course

Although the two are closely linked, for the sake of clarity the findings on conceptualisation and design are listed separately.

4.3.1 Summary of the findings on the conceptualisation of the Foundation Mathematics course

The Foundation programme was set up to improve first year pass rates and throughput for the National Diploma in Mechanical Engineering while broadening access to students from disadvantaged backgrounds.

The findings on the Model for integration

- The Foundation EMS course was set up as the 'core' through which support for mechanics concepts was supposed to take place.
- There was 'polarity' between the Programme designers and the EMS lecturers who had different conceptions of the role of the EMS course. The EMS lecturers had a conception of EMS as a materials course, while the programme designers conceived of it as a general course on the basic concepts in Engineering. This lack of equivalence on the concepts would have hindered conceptual development among the students. The EMS lecturers valued Materials concepts while the FS course and Programme designers valued the Mechanics concepts.
- The programme designers had been constrained by a national Technikon sector decision to include 2 mainstream courses in the programme which

meant that the Foundation EMS had to have at least the same outcomes as the mainstream EMS course. This amounted to 'polarity' between the National Technikon sector and the Programme designers.

- Mechanics concepts were an add-on to the EMS course which meant there was little 'affordance' between the concepts in EMS and in Foundation Science. There was not sufficient time for concept formation or reconceptualization of mechanics concepts in the EMS course (Only 2 weeks were spent on Mechanics, Fluid Dynamics and Thermodynamics).
- The only area for valid integration between EMS and FM was identified as the Tensile tests. The EMS course dealt with Mechanics concepts in a limited descriptive fashion, limited to verbal descriptions of definitions. This meant that the mathematically-based Mechanics concepts would not be able to be used in integration between FM, FS and EMS, at higher levels necessary for concept formation or reconceptualisation to take place (Sfard, 1991).
- The conception of the Foundation Mathematics course was it would prepare students for S1 Mathematics in the MDIPME; contribute to the development of the academic literacy of Mechanical Engineering; provide horizontal support for the basic concepts of Mechanical Engineering via EMS; language and content of Mathematics were to be integrated

The findings on the Foundation lecturers and students

Due to the above factors on 'polarity', 'affordance' and 'validity', although the model was thought of as 'fully integrated', it was more consistent with a 'fragmented model'. These conceptual flaws fundamentally influenced the Foundation lecturers' conception of integration, which meant that they transmitted the flaws in practice. The Foundation students bore the brunt of the implemented conceptual flaws. The Foundation lecturers' conception of integration evolved, which meant departing from the original Model, above). By the middle of 2005 the Foundation lecturers developed a conception which was closer to a 'fully integrated' one. The Foundation students' understanding of integration mirrored the evolution of the conceptual development of the Foundation lecturers. The Foundation staff had not been appropriately trained for delivering an integrated curriculum.

The findings on the vertical integration of the FM course

- There was 'polarity' of conceptual approach to integration of the FM course between the course designers and the lecturer. The FM course designers

adopted a 'connected' approach while the lecturer adopted a 'nested' approach. The 'nested' approach with its emphasis on deconstruction rather than use of concepts at higher levels would have led to a more 'procedural' understanding of Mathematics. All the student cohorts that were part of the study demonstrated 'procedural' approaches that were consistent with a 'nested' integration approach.

- Support for Mechanics concepts came directly from the FM course and not via the EMS course.
- The need for 'structural abstraction' and 'structural awareness' in the Foundation year would appear to have been partially met with the inclusion of S1 Mathematics in the 2002 and 2003 programme, while it would have been met to some extent with the inclusion of complex numbers within the FM outcomes in 2005 but in 2004, in its absence, a 'procedural' approach could dominate.
- 'Polarity' of meeting the needs of support for Mechanics 1 and meeting the needs of 'abstraction' for S1 Mathematics would have undermined vertical integration of FM with higher levels of Engineering.

The findings on Language support

The Language course was conceived of as meeting specific needs of a context where most of the student intakes were English second or third language speakers. The conception of giving language support to Mechanics concepts via EMS limited the support for FM and FS. Language support to EMS to assist in giving an introduction to the academic literacy was a valid concept. However, 'polarity' of the needs of Language and the needs of Engineering had to be effectively taken into account in the design of the language course.

4.3.2. The findings on the design of the Foundation Mathematics course

The conceptual flaws of the Foundation model led to design flaws. With this in mind the findings on the design aspects of the Foundation Mathematics course in context, are summarised below:

The findings on language support

- The Foundation EMS course was designed to start from the basics of Mechanical Engineering concepts, proceeding to materials and finally stainless steel;

- In 2002 the Language modules started with stainless steel with the last module being on integrated projects. This was a design flaw of materials being out of sync between EMS and Foundation Language (Communications Skills) and would not have supported integrated learning. Furthermore, the Communications skills text did not support any concepts beyond materials;
- Revisions of the Communications skills text only involved discussions with the EMS lecturer (stemming from a conceptual flaw) but still the module on integrated projects was still the last one for the Language course. A design disjuncture thus persisted;
- Only by 2005 was there a plan for integrating support for all Foundation level subjects including Mathematics (Appendix FF);
- The Language course focus on materials in Mechanical Engineering did offer opportunities for decoding the discourse of Mechanical Engineering;

The findings on horizontal support for mechanics concepts

- The conceptual flaw of support for Mechanics concepts via EMS meant that the design of the FM course was limited to not give direct support to FS, leading to less opportunities for conception formation (Sfard & Linchevski, 1994) and providing a basis for fragmented integration (Fogarty, 1991), with all the implications as in Chapter 2 section 2.5.3. p25 ;
- The limiting of the FS course to the first semester in 2002 and 2003, meant that there was a 6 month period before students took Mechanics 1 – another design flaw as concept formation would be limited (Sfard & Linchevski, 1994);
- The Foundation lecturers' evolution of conception of integration was reflected in the evolving design of integrated projects from 2002 to 2005. Only once EMS was dropped from the Programme in 2005 did the design reflect direct integrated support for the process of Mechanics concept formation (Sfard & Linchevski, 1994). For the first time, the process of cognitive conflict (Hubbard, 1998) was linked to the process of Mechanics concept formation. Clarity over sequencing of horizontal integration is thus an important design challenge for the Programme designers and lecturers;

- The 'literal equivalence' (Jacobs *et al*, 2002) of Foundation EMS and mainstream EMS inhibited Mechanics concept formation;
- An important design challenge when setting up an integrated curriculum is how to maintain the integrity of courses while supporting concept formation that may occur in several courses;

The findings on departmental support mechanisms

- A mechanism was not in place to ensure that findings of earlier evaluations or discussions on integration were readily available to Foundation staff;
- Various departmental mechanisms were in place (which was a form of action research) to critically examine the design of integration as well as affective issues that Foundation students faced- this was a strength of the programme;
- Some of the findings of the earlier evaluation (Jacobs *et al*, 2002) such as moderators and conditions of service of staff, were incorporated into revised designs of the Programme;
- Joint moderation of integrated assignments by Foundation staff around basic Mechanics concepts was necessary to establish minimum 'equivalence' (Goodsen, Espy, 1998) and for the process of concept formation to be effectively co-ordinated (Sfard & Linchevski, 1994);

The findings on vertical integration of the FM course

- The 'procedural' approach of the FM course designers and lecturer did not match the conception of the course;
- The FM course design only began to make reference to the outcomes of technologists, the CCFO's in 2005 (Appendix G);
- The conceptual 'polarity' (Jacobs, 1989) of support by the FM course for the pre-calculus –based Mechanics1 and limiting the development of 'structural awareness' needed for S1 Mathematics, was carried over into its design;
- The use of concepts at a higher level in order to consolidate them points to the design of an extended curriculum where S1 subjects are included in

the Foundation Programme and are 'stretched' over the year (Sfard, 1991);

4.4 Conclusion

The above summary sets the framework from which the implementation of the contextualised Foundation Mathematics course was evaluated. This topic is the subject matter of Chapter 5.

CHAPTER 5

EVALUATING THE IMPLEMENTATION OF THE MATHEMATICS COMPONENT

5.0. Introduction

Having critically examined the conception and design of the Foundation Mathematics course within the context of the model for the curriculum integration, the Study now turns to the crucial aspect of how it was implemented. First the selection of the students is discussed, followed by a review of how staff were selected and trained. This is followed by a discussion of how integrated assignments/projects were implemented. The inter-relation between the Foundation and mainstream staff is then evaluated. The Study thereafter turns to a review of the practical problems and the steps taken to address them.

5.1. How were the students selected?

Students were selected on the basis of having a Matriculation Certificate or its equivalent. Students had to have taken the subjects: English First or Second Language Higher Grade; Physical Science and Mathematics. Students would be directed to the Foundation programme if they had not met the departmental minimum criteria for any one of the 3 subjects, namely a minimum of a D Standard Grade result in each of Mathematics and Foundation Science but a minimum of a Higher Grade D for Second Language English.

In the years 2002-2004 students were taken on a first come, first taken basis, while in 2005 the students were selected on the basis of obtaining results the closest to the minimum entry criteria for the Department. This meant that for 2005, about 47% of the class did not meet the minimum entrance requirement for Mathematics, the lowest of the four cohorts (Table 5.1). The change in selection process did not appear to significantly influence the spread of Physics and English marks of the students. The full breakdown of the symbols and grades of the cohorts is contained in Appendices OO (1-4), while Table 5.1 is a summary of some of the trends across the period of study.

Table 5.1. Comparative trends of matriculation results of student cohorts

Comparative trends of Matriculation results				
Percentage of cohort wrt subject	2002	2003	2004	2005
% SG Maths	100	100	100	100
% E or less Maths	66.6	55	72.7	46.9
%D or less Maths	90.8	77.5	93.9	68.8
%SG Physics	97	97.5	97.1	100
%E or less Physics	75.7	82.5	88.2	81.3
% D or less Physics	93.9	97.5	97.1	96.9
% 2nd Lang HG Eng	90.9	70	79.4	93.8
% E or less Eng	51.5	37.5	50	68.8
% D or less Eng	87.5	72.5	76.5	87.5

5.1.1. Discussion of the Matriculation results of the student intake

The following trends or significant points emerged from the data:

- All student cohorts had taken Mathematics on the Standard Grade;
- Most students had taken Physics on the Standard Grade. In each of 2003 and 2004 one student was taken into the Programme who did not have Physics as a subject;
- At least 70% of each cohort had taken English as a second or third Language;
- A minimum of two-thirds of each cohort scored less than 60% for Mathematics, while half or more scored less than the 50% minimum entrance criteria;
- The Physics results were generally lower than the Mathematics results with almost the entire class scoring below 60%, and three quarters or more scoring less than the 50% minimum entrance criteria;
- About three quarters of each cohort scored below 60% for their English while about half scored less than the 50% minimum entrance criteria (the 2003 cohort could be regarded as an anomaly as only 37.5% of the class did not meet the minimum criteria);
- The cohorts fit the profile of the course designers, namely that they would be mostly second language English speakers with Mathematics and/ or Physics learning difficulties.

From the initial examination of the data it appeared that student performance at matriculation level in mathematics was not an indicator of performance in Physics. This is discussed in greater detail in the next Chapter.

5.2. How were the staff selected and trained/supported

As much as it is important to evaluate the profile of students it is important to evaluate the staff who presented the programme (Galbraith, 1984).

It has already been established that the 2002 Foundation staff did not have tertiary teaching or professional engineering experience (See Table 4. 2). They also had no training in the facilitation of an integrated curriculum, nor of techniques of facilitating learning of under-prepared students (Jacobs *et al*, 2002).

In 2003 a Foundation Science lecturer, who was an Electrical Engineer, was appointed, but due to being offered a contract position elsewhere she left at the end of her first year. She had had no teaching experience prior to starting with the Foundation Programme. Besides this, the staff for Foundation Communications Skills and Foundation Mathematics had pre-tertiary education teaching backgrounds. The Foundation Drawing, Manufacturing and EMS lecturers of 2003 had a Mechanical Engineering background, but no training in facilitating an integrated curriculum nor did they have training in the facilitation of learning of under-prepared students.

Tables 5.2 summarises the profile of the lecturing staff for the period 2003:

Table 5.2 Foundation Staff training, experience and qualification for 2003

Lecturer	Qualification	Training for tertiary facilitation	Training for integrated curriculum	Training for facilitating under-prepared students	Engineering background
Mathematics	Higher Diploma teaching (Mathematics and Physics)	None	None	None	none
Science	BEng (Elec)	None	None	None	Electrical engineering
Communication Skills	Higher Diploma English	None	None	None	none

Manufacturing	Btech	None	None	None	Mechanical Engineering
Drawing	Btech	None	None	None	Mechanical Engineering
EMS	Mtech (ME)	None	None	None	Masters in Mechanical Engineering
Computer skills	Diploma IT	None	None	None	IT

Table 5.3. summarises the profile of the lecturing staff for the period 2004-2005:

Table 5.3. Foundation staff training, qualifications and experience for 2004 and 2005

Lecturer	Qualification	Training for tertiary facilitation	Training for integrated curriculum	Training for facilitating under-prepared students	Engineering background
Mathematics	Higher Diploma teaching (Mathematics and Physics)	2004 (induction course at CPUT)	None	None	none
Science	Hons (Microbiology)	2005 (induction course at CPUT)	None	Experience at bridging college	None
Communication Skills	Higher Diploma English	2005 (induction course at CPUT)	None	None	none
Manufacturing	Btech	None	None	None	Mechanical Engineering
Drawing	Btech	None	None	None	Mechanical Engineering
EMS (2004 only)	Mtech (ME)	None	None	None	Masters in Mechanical Engineering
Computer skills	BEng (Mech)	1997	None	None	Mechanical

		(induction at Pentech-precursor of CPUT)			Engineer
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5.2.1. Discussion of the Foundation staff profile

The following trends or significant points emerged from the data on the staff profile:

- None of the Foundation staff received training in facilitating an integrated curriculum;
- Training for facilitation at tertiary level was sporadic and not all staff received this training;
- Only one of the staff had prior experience of facilitation with under-prepared students;
- Most of the staff with Mechanical Engineering experience did not have training for facilitation at tertiary level;
- In 2002 and 2003 none of the staff had received training in facilitation at tertiary level;
- In 2004 and 2005 there appeared to be a mismatch of skills in that perhaps the lecturer who was a Mechanical Engineer should have facilitated Foundation Science and not Computer Skills.

The lack of training in facilitation at tertiary level could have been a source of the 'procedural approach' (Case & Marshall, 2004) generally adopted by the lecturers, who would tend to fall back on their own experience, in which the 'transmission'/teacher-centred mode of teaching was dominant (Brookhart & Freeman, 1992).

Students identified and criticised the 'transmission' model predominantly used by the lecturing staff, as the following student statement, indicates:

More work should be done by students themselves not by lecturers because in S1 most of the work is done by students themselves. More projects, assignments etc should be done (Student 2003 S06).

Without realising it, students exposed the lack of appropriate training of the lecturing staff in tertiary facilitation as well as their lack of training in facilitation of an integrated curriculum.

That none of the staff had received training in facilitation of an integrated curriculum was an inhibiting factor in the implementation of the model, namely that teaching was 'contextualised' in a weak sense. In other words, without the knowledge and experience of facilitation of an integrated, the lecturers would more easily be prone to errors such as forcing together aspects that should have been taught in parallel, or exhibiting 'polarity' in their understanding of concepts that occurred in multiple subjects/disciplines- the result would have been a 'fragmented' approach leading to 'surface' learning. At the same time the above student quotation highlights the possible influence of this study as interim findings were presented to the Foundation lecturers before their mid-year integrated project review in 2005 resulting in them realising that their approach to integration was not adequate:

We discussed a new integrated approach as Foundation lecturers, before we re-looked at the project marks. We had to do something, something was not right with the project (Lecturer FL04).

This reflects a realisation that a 'fragmented' approach to integration did not lead to student cognition and that a new approach was necessary.

5.3. How did the Foundation staff relate to one another as well as the rest of the mainstream staff?

In 2002 all the Foundation staff were part-time which meant that they did not meet regularly and they were not part of departmental meetings (Jacobs *et al*, 2002). This meant that there was minimal contact with colleagues and insufficient opportunity to plan integration, to follow it through or even deal with difficulties with implementation. In the latter half of the year the Foundation lecturers met weekly which meant that there were now opportunities take initial steps towards integration such as planning sequencing of teaching.

Since the start of 2003 the nature of the interaction between Foundation staff and the mainstream staff changed:

The benefits of regular interaction between mainstream and foundation staff as a result of the improved employment status were noticed by a mainstream staff member:

Ever since the Foundation staff were put on contract [at the start of 2003] they have been with us in staff meetings- they must be on the same page as us; they also teach S1 subjects so they know what to prepare students for; it's sad that the manufacturing person is part-time- I am a Manufacturing man so this is not getting enough attention (Lecturer Main L04).

Even though Foundation staff had not received training in facilitating of an integrated curriculum, that they also taught mainstream subjects would have assisted with the aspect of vertical integration as, except for Manufacturing, they gained direct knowledge of the mainstream subject they were preparing students for.

This 'connected' approach (Fogarty, 1991) to vertical integration is also supported by the course outline that had to be prepared in advance of course presentation and handed out on the first day of lectures (See Appendix H).

The lack of vertical integration for Manufacturing was felt by students as is shown by the following:

We need to have an introduction to hand tools in the first semester to introduce us to Manufacturing (Student 2005 S07).

The lack of prior support for the Manufacturing subject can be seen as resulting from a design flaw in the model.

The lack of training in facilitating an integrated curriculum was also reflected in the staff meeting only around integrated assignments and not on the Foundation Programme as a whole:

Since 2003 Foundation lecturers met mostly during the 7 to 8 weeks of the integrated project (per semester) to set it up, mentor groups, conduct presentations and mark and moderate assignments. We always meet to discuss 'at risk' students and how we can assist (Lecturer FL04).

Thus the design flaw of not training staff in facilitating of an integrated curriculum would have narrowed the impact of attempts at integration.

The evidence is that Foundation staff were part of departmental activities, met mainly around integrated projects and to discuss 'at risk' students. They were also part of the departmental review of policy on integrated projects (Appendices P-T). Besides the shifting of the chapters on Atomic structure and gases to the beginning of the Physics book (Spies & Mahomed, 2004), the integrated projects discussions and the mid-2005 integrated project review, there is no evidence of a concerted effort among the Foundation lecturers to systematically plan and implement a fully integrated curriculum. A Foundation co-ordinator was appointed only in mid-2005. This meant that the integrated model from 2002 to the middle of 2005 was characterised by a 'fragmented' approach with attempts at sequencing on an *ad hoc* basis. This would have meant that, during this period, from a structural point of view, a 'procedural' learning approach was being fostered (Case & Marshall, 2004)

5.4. The implementation of integrated assignments

As integrated assignments were the main vehicle for co-ordination of teaching and learning, the study reviews them (Jacobs *et al*, 2002; Appendices V-EE) over the period of this study (see Table 5.4 below).

Concept formation in the minds of students requires time and a process (Sfard & Linchevski, 1994). This meant that 'interiorisation' and 'condensation' would precede the process of 'reification'. For integrated practicals this meant a prior process on a particular concept before its use in the practical. If the prior preparation has been adequate, then the process of 'cognitive conflict' together with immediate feedback would have given opportunities for reification of the concepts being consolidated in the minds of the students. These are the aspects being reflected in table 5.4. below:

Table 5.4. The implementation of integrated assignments

Year	Task	Linked to Mechanics concept	Linked to Maths concept	Practical activity	Cognitive conflict	Timing of feedback	Learning approach
2002	report	no	no	no	yes	End of semester	fragmented
2003 1 st sem	Community report + tensile test	No	Calculation of stress	Community survey + tensile test	yes	End of semester	Fragmented with partial sequencing
2003 2 nd sem	Manufacture collapsible washing line	No	Mass calculations	Manufacture from given specifications	Yes	End of semester	Sequenced but no link to mechanics
2004	Community project and building of scale model	no	no	Community survey + build of model from scrap materials	yes	End of semester	Nested
2005 1 st sem	Community project	No	no	no	yes	End semester	fragmented
2005 2 nd sem	Integrated pracs: equilibrium; friction; velocity ratio	yes	yes	Pracs related to mechanics concept	yes	Engage during prac and immediate feedback	Fully integrated

5.4.1. Discussion of the implementation of integrated assignments

The following trends or significant points emerged from the implementation of integrated assignments:

- Except for the latter half of 2005 none of the integrated assignments were linked to Mechanics;

- For the 2005 integrated practicals the feedback was during the practical and immediately afterwards through interrogation on why theory differed from practice;
- The 2005 practicals provided opportunities for Mechanics concepts to be seen in equivalent forms (Goodsen- Espy, 1998), whereas the assignments did not;
- There was a prior process of teaching of the Mechanics concepts and the Mathematics needed before hand that allowed interiorisation (Sfard & Linchevski, 1994) of these concepts prior to the practicals, while in the other assignments this was not the case;
- The 2005 practicals , through, the use of appropriate equivalent forms, immediate engagement and cognitive conflict (Hubbard, 1997), pushing students' thinking of process-object duality (Sfard, 1991) allowed the process of concept formation to proceed to condensation and reification (Sfard and Linchevski, 1994), while in the other assignments there were no similar processes;
- The cross-questioning of students in the other assignments listed in Table 5.4. above (except for the integrated practicals of 2005), in the absence of a link to the Mechanics concepts whose formation or reconceptualisation they were supposed to be promoting, can be more appropriately described as being 'conflict' rather than 'cognitive conflict' exercises.

5.5. The relation of the Foundation Mathematics course to the Foundation Science course and to the mainstream

Against the backdrop of a 'fragmented' approach to integration of Foundation Mathematics (FM) into Foundation Science(FS), as far as the Programme model (Figure 4.1) is concerned, evidence of FS content within the FM course is now evaluated.

The many areas for FM to support Mechanics concepts have already been established (Table 4. 4). The areas which occur in the FM text (Cloete & Mahomed, 2004) which do support Mechanics concepts are given in table 5.5 below:

Table 5.5. Areas in Mechanics which are directly supported in the FM course

Chapter in FM text	Mechanics concept
Use of the calculator	Linear motion; period of pendulum; stress calculations; toppling speed (angular motion)
Manipulation of formulae	Equations of motion
Data handling and graphs	Linear motion; float height in vortex; flow rate in vortex (theory vs practical); modelling of vortex (parabola)
Geometry	2D areas and properties of circles for centre of gravity calculations
Areas & Volumes	Areas and volumes of 2D and 3D shapes; centre of gravity
Linear and quadratic equations	Linear motion
Percentages	Percentage errors
Trigonometry	Resolution of forces into components
Limits, definition of derivative; introduction to the integral	Linear motion, derivation of equations of motion through integration

Several assessments of the FM course were examined from 2002 to 2005 and evidence found of all the areas as outlined in Table 5.4, occurring therein, except for the use of Derivatives and the Integral; Geometry was only fleetingly covered (for example see Appendices F1 ; G1 & G2). Trigonometry is the second last chapter in the Mathematics text which means that it would have been out of sync with the FS course when Forces (requiring the use of it) is one of the opening Chapters (Cloete & Mahomed, 2004).

It follows that the FM course, by the way it is structured, did support the FS course as well as Mechanics 1, albeit not 'in sync'. This is further supported by the following:

[FM is] good preparation for S1, especially Maths and Mechanics – a lot of it is the same as Mechanics 1 (Student 2002 S02).

Students from the 2004 cohort also concurred with this support of FM for FS and for Mechanics:

I think that Foundation Maths played a big role even in Foundation Science. It even played a big role in S1 Mechanics and Maths (Student 2004 S01).

However, except for the second half of 2005 (Appendices BB to EE) there was no prior evidence of practicals being set up 'in sync' with teaching of mathematical and Mechanics concepts. The absence of integrated practicals would have weakened student concept formation tending to be limited to 'recognition' and/or 're-presentation' (Cifarelli, 1988).

Evidence of 'metacognitive' mathematical skills being developed among Foundation students and of the possibilities of 'structural abstraction' or even 'structural awareness' developing from the way the FM course was presented, was:

[FM assisted with] how to generate ideas, how to go through that process, a method (Student 2002 S01).

This was further supported by the following:

...critical thinking if calculating flow rating and you get x, you know it's impossible to get that. You sit back and think in actual fact that's impossible (Student 2003 S01).

The FM course gave students the motivation to work in other subject areas:

Getting work in Maths and learning to practice helps to work on your self discipline. If we were not getting work in Maths we would be reluctant to do work in other subjects (Student 2004 S03).

Student 'metacognition' was promoted among the 2005 cohort as well:

We had to come up with a conclusion why we were wrong, why there was a deficit for the answer (Student 2005 S02).

The above quotes are also evidence that although the assessments would have encouraged 'procedural' learning, the way the FM course was presented extended to encouraging student 'metacognition'.

Summary of the relation of the FM course with FS and with the mainstream

- The model did not support direct integration of FM into FS
- The FM course did have substantial FS content and this was presented out of sync with the FS course, except for the period after the middle of 2005
- The FM course did promote student 'metacognition' but would have been limited by the 'procedural' approach to assessment in FM

The study now turns to a review of the practical problems that occurred as well as the steps, if any, to address them.

5.6. What caused practical problems and how were they addressed?

There were a number of practical problems. The main ones are listed below:

Student alienation

The 2002 students felt a sense of alienation from the department (Jacobs *et al*, 2002). This could have been due to a number of factors and was not adequately addressed as evidenced by a response to a questionnaire in issued in 2003:

The student cohort of 2004 Students felt like outsiders as they did not get the same reception and treatment as other students in the department:

The foundation students they must be really made to feel that they are part of this Mechanical Engineering. No to say that they are half students of the department (Student 2002 S07).

One of the responses to alienation was the organising of class outings from 2003 onwards:

I liked the break away with lecturers with lecturers communicating with students. Foundation rocks!!! (Student 2004 S05).

This did alleviate student sense of alienation.

Greater interaction with students in class was encouraged by the department:

First of all, I liked the way the lecturers were with the students, interacting with them not putting them far away and ignoring them (Student 2003 S08).

This also appeared to have attenuated student alienation.

Another response to encourage students was to bring in ex-Foundation students to motivate them:

From 2004 we brought in ex-Foundation students as motivational speakers. This worked very well. We also took them on site visits to engineering firms (Lecturer 2005 FL04).

This step also yielded positive results.

In all, several steps were taken to alleviate student alienation and it is noteworthy that the cohorts of 2003 up to 2005 did not raise such concerns.

Staffing issues

The 2002 lecturers were all part-time and were not always available for student consultations; there was no co-ordinator; (Jacobs *et al*, 2002). Most Foundation staff (except the Manufacturing lecturer) were appointed on contract from 2003 and a Co-ordinator was appointed in mid 2005.

The recommendations of the 2002 evaluation with respect to the Foundation EMS to overcome the question of a literal equivalence were not brought to the attention of the new 2003 Foundation EMS lecturer. This was due to staff turnover inevitable where the staffing component were still on contract. Not only the literal equivalence continued but the course developed deeper on the basis of Material Science than of addressing the concepts in Mechanics.

The recommendations of the earlier evaluation (Jacobs *et al*, 2002) were not made available to the Foundation staff except the FM lecturer in 2003.

The manufacturing lecturer was part-time. This was only a problem for the 2004 and 2005 cohorts. This has been addressed through the secondment of a mainstream

lecturer to facilitate this subject. If left in the hands of part-time staff, the problem of lack of necessary co-ordination for integration, would persist.

The lecturers' lack of training in facilitating an integrated curriculum also resulted in inconsistent marking of integrated assignments:

I like the course very much but when it comes to project it makes me very sick because there are mentors [lecturers] that have favourite students so that is very very unfair (Student 2004 S06).

This reflected 'polarity' in conceptual emphasis among lecturers as a result of a lack of training in facilitating an integrated curriculum.

The complaint preceded the mid-2004 departmental review of integrated assignments and a new policy of joint moderation was established as part of a mechanism to achieve greater consistency in marking (see Appendices P to U).

The lack of training in facilitating an integrated curriculum also resulted in too few opportunities in the course for conceptual cognition:

[we need] more practicals and lecturers should explain where the two meet. Also relevant Chapter, where they meet in real life. (Student 2005 S08).

It is interesting that the above comment came from students of the 2005 cohort as they could identify the usefulness of 'full integration', having experienced aspects of it in the latter half of their foundation year. Creating more opportunities for meaningful integration to support student cognition of engineering concepts, is a design challenge for the Foundation Programme.

Administrative issues

There were a number of administrative problems that students faced that could have negatively impacted on their academic performance:

Students did not get loans like other students in 2002. The Department did negotiate with the National Student fund so that students started getting loans from mid 2002;

Students' progress reports from the Engineering Faculty were not posted to them on a quarterly basis as with other students:

We never get our results, we have to ask our administrator and she is overloaded (Student 2005 S02).

This difference in treatment of Foundation students could be a contributing factor to a sense of alienation among students. This problem still persists and should be addressed by departmental administrators.

Scheduling Mathematics for afternoons posed a problem as they were probably tired, having reached close to 'saturation point' for internalising new information:

I suggest that Maths must not be scheduled for the afternoon (Student 2003 S05).

This problem was addressed in the 2004 timetable when FM and FS contact time was then scheduled for morning sessions rather than also in the afternoons as well (MAR100 is the code for FM while MIJ100 is the code for FS, see appendices NN1 & 2).

The 2003 cohort complained over the class size (See Table 5.6). With limited resources for lecturers and tutors, the ability to provide essential feedback to students that is necessary to assist with their cognition of Engineering concepts, having too large a class would compromise this process. A class size of 48 students was too large for the purposes of the Foundation Programme. Even a class size of 42 was beyond the numbers required for effective teaching and learning of a Foundation programme:

The class is way too big. There is no individual attention (Student 2003 S07).

Class sizes were adjusted downwards as a result of student complaints (see Table 5.6). With the limited resources at hand, finding the optimum class size should be further investigated.

Table 5.6. Class size of the respective cohorts

Year	2002	2003	2004	2005
Class size	39	48	42	39

Students complained about long periods causing them to lose concentration:

One class takes so much time, and students land up sleeping and bored. You must not give students 3 periods at one process or time (Student 2003 S08).

The process of internalising of a concept, from 'interiorisation' to 'reification' requires an extended time and requires reflection. Having extended sessions such as 3 consecutive periods, does not give the requisite time for conceptual cognition. This was partially rectified in that from 2004 onwards Mathematics and Science were only presented in double periods (see Appendices NN1 &2).

Academic support

There were a number of areas where academic support for students were overlooked or insufficient in the model conception and design:

Students felt that they needed to have Foundation Drawing included. Most entry-level students were not from Technical schools and did not have experience in engineering drawings:

We need to have Drawings included as most of us don't do it at school (Student 2003 S06).

Foundation Drawing was included from the second semester of 2003 and from the start of 2004 was presented as a full year course (see Appendix NN2).

Students felt they needed more support in FS. While this was evidence that the model of integration was not effective in supporting student cognition in Mechanics concepts, it also demonstrated that students found cognition of these concepts difficult:

There should be tutors for Foundation Science just like we have in Maths (Student 2004 S08).

Tutors were provided in 2005 but they lacked the necessary skills:

The Science mentors did not make any difference, they used to struggle solving the problems (Student 2005 S04).

The lack of requisite skill among undergraduate mentors reflected a broader problem of a weak conceptual understanding of Engineering fundamentals among many mainstream MDIPME students. This problem was partly solved by taking Masters students:

We took Masters students as tutors but we really had a problem to find suitable tutors (Lecturer 2005 FL01).

How effective these masters students were, should be further investigated.

5.7. Summary of the evaluation of the implementation of the Foundation

Mathematics course

A summary of the evaluation of the FM course in the context of the Foundation Model (Figure 4.1) is presented below:

Student selection

- The intake of Foundation students for the years of this Case Study, 2002 to 2005, fit the intended profile of the Programme designers, namely that it would provide access to students who would have met entry criteria for the CPUT but not the minimum criteria of the Department of Mechanical Engineering (CPUT, 2004);
- Although students had mostly not met the entry criteria for Mathematics, they appeared to have greater difficulty with Physics. Most students were second language English speakers;

Staff selection and training

- Foundation lecturers had not been trained in facilitation in an integrated curriculum and only some received *ad hoc* training for tertiary level facilitation;

- There was a possible mismatch of skills in 2004 and 2005 when a Mechanical Engineer presented the Computer Skills course instead of being utilised to facilitate Foundation Science;
- A programme co-ordinator was only appointed from mid-2005.

Implementation of horizontal integration

- The Foundation lecturers met mostly around integrated assignments and not to co-ordinate teaching and learning in general as required with a fully integrated curriculum (Lake, 1994);
- The integrated assignments (except for the second semester of 2005) were not linked to support concept formation in Mechanics;

Implementation of vertical integration

- The FM course, within itself supported both FS and Mechanics concepts, but these were not related to practicals nor was it co-ordinated with the FS course;
- The FM course did promote student 'metacognition' in Mathematics to some extent but were constrained by a 'procedural' approach to assessment;
- There was no evidence of differentiation or the section on integrals, being covered in the FM course. (Students in 2002 and 2003 took S1 Mathematics as part of their Foundation year);

Practical Problems

There were a number of practical problems (all of which were not addressed): alienation of students; lecturers were part-time and not sufficiently available; progress reports were not sent to students; Mathematics was presented in the afternoons up to 2003; the recommendations of the 2002 evaluation of Jacobs *et al* was not made available to most of the Foundation lecturers; in 2002 no support was offered for Mechanical Drawings; the 2003 cohort complained about the large class size; tutors were needed for FS and when provided were not skilled enough; in 2002 and 2003 triple periods of subjects hindered learning; there had been inconsistent marking of integrated assignments; there were too few practicals and students asked for class work to be made more relevant.

5.7. Conclusion

The conceptual and design flaws of the Foundation model constrained the implementation of an integrated curriculum, although there were also a number of practical problems that students and staff encountered that also inhibited student cognition.

The Evaluation has now covered the ground of conception, design and implementation of the Foundation Model. It is appropriate, therefore to turn to an Evaluation of the impact of the FM course. This is the subject matter of the next Chapter.

CHAPTER 6

EVALUATING THE IMPACT OF THE INTEGRATED MATHEMATICS COURSE

6.0. Introduction

Critical to a formative evaluation of an aspect of a Programme, once having evaluated the conception, design and implementation thereof, is to evaluate its impact (Babbie & Mouton, 2001). In this case of evaluating an integrated curriculum, the expected outcomes of 'full integration' include a more integrated knowledge base, deeper conceptual understanding and the promotion of positive attitudes (Lake, 1994). The expected outcomes for partial integration would be expected to be consistent with Table 2.2, depending on which level of integration was actually implemented. The findings on the expected impact would either be consistent with it and thereby cross-validate it, or the findings could contradict the theoretical predictions.

This Chapter discusses the evaluation of the impact of the FM course in three parts: First it evaluates the impact of the affective issues and practical problems associated with the implementation of the Foundation Programme, and the steps taken to address these over the period of the study; Secondly, it evaluates the impact of integration of FM into FS; Thirdly it evaluates the impact of the integration of FM into S1 Mathematics (vertical integration); the Chapter concludes with a summary of its main points and conclusion.

6.1. The impact of affective issues and practical problems

In the first year of the programme students were affected in a number of ways due to structural problems around implementation (see section 5.6 , for example, alienation, academic support, tertiary academic skills, staffing and administrative problems), which resulted in low levels of motivation; negative feelings towards the Programme; lack of taking responsibility for their own learning; the Programme was seen as a 'barrier' rather than a 'gateway' to studies in Mechanical Engineering(Jacobs *et al*, 2002).

A number of steps were taken to attempt to overcome the structural problems that Foundation students faced (see 5.6). Mechanisms to enhance student sense of

belonging, especially among academically 'at risk' students, would have positively influenced their performance (Hixson & Tinzmann, 1990). The impact of the continuing structural problems and steps taken to attenuate or overcome them are examined below.

6.1.1. The impact of measures taken in 2003

This study is able to examine the impact of the Foundation Programme in some detail for this year due to the high response rate (38 out of a possible 48) to a questionnaire issued in 2003 (Appendix C). For the purposes of delineating trends, no distinction is made between categories 'agree' and 'strongly agree' on the one hand and 'disagree' and 'strongly disagree'. The shortcoming of not having a fifth column, namely 'do not know' is overcome due to several cases where respondents left the relevant line blank. A blank line is grouped together with a 'disagree' response for the relevant question, except for question 5, where the blank line is grouped with 'agree' responses. A breakdown of some of the responses is given in Table 6.1 below:

Table 6.1. Student evaluation of Foundation Programme in mid-2003

Question	agree	disagree
1. The Mathematics lectures have improved my understanding of the subject	35	3
2. The Mathematics lectures have assisted in understanding other subjects better	20	18
3. The Physics lectures have helped me improve my understanding of the subject	34	4
4. The Language lectures have improved my English language skills.	27	11
5. Proficiency in English is not a requirement for academic success	12	26
6. I felt comfortable enough to approach the lecturers when I did not understand the work	28	10
7. I am confident that I will pass all the subjects done this semester	36	2
8. The Foundation course does not offer enough support to students who are struggling to cope with the work	28	10

Discussion of the responses in Table 6.1.

The responses to questions 4 and 5 on English, that their English was not improved and that English proficiency is a requirement for success, appears to be linked with the fact that in this year only about 40% of the cohort did not make minimum entry criteria (in Language) for admission to the Mainstream programme. However it appears that even among those who had made the minimum criteria for English, did benefit from the Communications skills course. The question still arises, as it did in 2002, as to whether students who meet the entrance requirement for a subject should be compelled to take the respective Foundation subject (Jacobs *et al*, 2002). This should be matter for future research.

Student confidence appears to have been heightened in Mathematics and Physics. This is also shown in the high number of students who were confident of passing all subjects.

High confidence among students is also shown by about $\frac{3}{4}$ of respondents who felt comfortable enough to approach lecturers with problems they had. However, that $\frac{1}{4}$ of students felt they were not getting enough support and $\frac{1}{4}$ felt they could not approach lecturers with their difficulties shows alienation was still a factor, albeit reduced from the previous year.

That just more than half of respondents felt that Mathematics improved their understanding in other subjects points to fragmented integration, or at best a partially sequenced integration, leaving students to 'join the dots' (making the connections of equivalent uses of concepts in other subject areas).

6.1.2. Other aspects of the impact of measures taken to address practical problems and alienation of students, over the period of the case study

Evidence of the impact of the steps taken to address student alienation and problems they faced (see 5.6.) is presented below:

There was a greater sense of pride, motivation, of taking responsibility for learning, of regarding Foundation as a gateway, and adjustment to tertiary learning. Evidence of this is exemplified by the following:

Students felt a greater sense of pride and motivation:

Foundation Rocks, I'll stay one to the end!!! ...I liked everything about the course, please do not change what you are doing, it really help ME in a lot of ways! (Student Q12003 S02).

This is further supported by the following:

I never liked science so much but everything is more interesting and give you a edge to study (Student Q1 2004 S03).

Students showed signs of overcoming the earlier sense of alienation:

I think this course helps you a lot and prepares you for the future (Student Q1 2004 S01).

This is further supported by the following, which showed that the attempts such as outings were assisting students with social integration:

I liked the camp and the second chance to becoming an engineer (Student Q 2004 S03).

Students also showed signs of developing the required tertiary academic skills:

I did not know how to speak in front of people but I learnt to do that in Foundation...you had to have back up, where you found it, how you found it, was it your information. Plagiarism is a definite no-no (Student 2004 S02).

Students took responsibility for aspects of their own learning:

This is a tertiary institution, we knew that everything is in English so we must make the effort to practice it (Student Q 2005 S04).

Students showed signs of awareness of the skills and attitudes that would be required in the field of Mechanical Engineering (acquiring, to some extent the discourse of Mechanical Engineering):

You learn your environment and get a picture of what type of environment you'll work in. So you have time to think whether you want to continue with Mechanical Engineering (Student 2004 S01).

That there are still some challenges is exemplified by the following:

The lack of training in facilitation of an integrated curriculum meant that lecturers did not always consider the requisite time that students needed for conceptual cognition:

Lecturers rushed to finish the syllabus (Student 2003 S03).

A weaker conceptual knowledge base would have resulted from the errors of the lecturers' lack of training. This is further supported by the following:

There should be more integration as most students struggle with Foundation Science (Student 2003 S01).

Students had identified their weak conceptual understanding in Mechanics concepts and recognised a design flaw in the model (lack of integration to support Mechanics concepts).

Although students did not know the terms such as 'reification', 'cognitive conflict' and 'the use of concepts at higher levels' they realised more regular and timeous feedback to them would strengthen their conceptual understanding of engineering fundamentals:

If they [the lecturers] were more involved during the year to give feedback it would improve the course. Also more S1 subjects should be in the Foundation course (Student 2004 S02).

The students thus also picked up on the lack of training of the Foundation lecturers as well as a conceptual and design flaw in the model which did not adequately present opportunities for use of concepts at higher levels (through introducing more S1 subjects at Foundation level).

All S1 subjects, including Computer skills, are now in the Foundation programme and extended over the year (Appendix QQ). The other points are challenges to the 2007 Foundation course lecturers.

The improvements to the course would have had a positive impact on student performance and this has to be borne in mind when specifically evaluating the impact of the FM course itself. The Study turns now to a closer evaluation of the impact of the FM course.

6.2. The impact of the integration of Foundation Mathematics into Foundation Science

The conceptual and design flaws (see the summary in 4.3) together with the implementation factors (see the summary in 5.3 as well as Table 5.4) with respect to the Programme Model (Figure 4.1), meant that in broad terms, there was weak (fragmented) integration of FM into FS from 2002 up to the middle of 2005, while from the middle of 2005 to the end of that year, can be better characterised as strongly (fully) integrated. Table 5.4 also gives evidence that in 2003 and 2004 there were also elements of sequencing of integration of FM into FS.

It is to be expected that there would be evidence of stronger Mechanics concept formation among the 2005 cohort than previous cohorts. Such further evidence is now presented together with triangulation thereof:

6.2.1. Evidence of concept formation

In the focus group interview with students from the 2005 cohort the following statements were made:

The student cohort of 2005 demonstrated a higher level of having internalised mechanics concepts. This is shown by the following:

Due to this [FM] course you started to think about things mechanically, like why do doors open that way and handles turn that way (Student 2005 S02).

This shows reification (Sfard & Linchevski, 1994) of mechanics concepts as ideas are no longer linked to the original mathematical calculations.

This is further supported by the following:

Foundation gives you that engineering thought (Student 2005 S01)

Students showed that they had a 'more integrated knowledge base':

It teaches us the basics of engineering as a whole (Student 2005 S03).

This is consistent with the expected result of a 'fully integrated' curriculum.

Greater emotional development, consistent with integrated group work, was also reflected by the students of the 2005 cohort:

It changes your mindset (Student 2005 S04).

This is further supported by the following:

In Foundation we grow up (Student 2005 S05).

That the greater conceptual development was mainly due to the 'fully integrated' practicals in 2005 and not due to other factors is shown by the following:

For me it took a long time to decide to do Mechanical Engineering. Always wanted to learn about cars and that stuff. When I started doing forces, equilibrium, I realised I belong here (Student 2005 S03).

6.2.2. Triangulation from questionnaires

Further support for the greater conceptual understanding of the 2005 student cohort can be gauged from the returns from the 2005 questionnaire (Appendix A). These questionnaires were given to a student representative from each of the respective cohorts and they were supposed to be handed back to the departmental secretary. A cautionary note here however is that the returns of this questionnaire were too few for a statistical analysis (only 13 were returned indicating that the questionnaire was too long). Responses to open-ended questions such as question 22 'What did you like about the integration of Foundation Maths into the Foundation Science course?' (Appendix A), are used with this limitation in mind.

The 2005 student cohort exhibited 'metacognitive' skills and an 'integrated knowledge base':

It [integration of FM with FS] helped to solve a problem I could not solve in foundation science. It helped to see exercises in a different way and to try and come up with other ideas of solutions (Student 2005 QS01).

This is further supported by the following:

The integration of these subjects are great ideas, where Mathematics can be bonded in scientific experiments...I liked everything about integration, especially the calculations and seeing what you busy with (Student 2005 QS02).

Integration of FM with FS for the 2005 cohort, led to greater conceptual understanding of Engineering fundamentals:

It changed in a way that I got a better understanding of the concepts (Student 2005 QS03).

That the greater concept formation came from the change in design from the second half of 2005 of integrated projects is exemplified by the following:

At the beginning (last semester) I was not pleased with the idea of Intergrated [*sic*] project. I liked the fact that the strategy of the intergrated [*sic*] project was changed (Student 2005 QS03).

Due to the weakness of the use of these questionnaires (with its low response rate), it is necessary to further triangulate the claim of this thesis that the student cohort of 2005 developed greater conceptual understanding of mechanics principles due to attempts at 'full integration'.

6.2.3. Triangulation by 'muddy cards'

A 'muddy card' was filled in by students immediately after completing the equilibrium and friction practicals (Appendices BB & CC). There were twenty six muddy cards returned out of a class of 39, which gives a better indication of the impact of an

attempt at integration than the questionnaires discussed in section 6.2.2. All returns spoke positively of the integrated assignment with only three raising reservations. Evidence of concept formation (in the context of sequenced lectures on the topics having preceded the assignment) is presented. Evidence of equivalence (Sfard, 1991; Goodsen-Espy, 1998) and cognitive conflict (Hubbard, 1997) also emerge as important aspects of concept formation as predicted by learning approach theory:

The use of a concept in 'equivalent' form, the theoretical and the practical, assisted students to grasp the Mechanics concept of equilibrium of forces:

I've learnt a lot because to me it was just a theory that when forces are in equilibrium their resultant is zero but from these practicals I've seen that (Student MS04).

This is supported by the following:

Basically what we learnt was an addition to our knowledge because we only knew the theoretical [*sic*] background about the experiment... it really helped us a lot just to see in live what was happening "seeing is believing" (Student 2005 MS03).

Students also showed that they had improved 'metacognitive' skills:

Learning is a process and I have learned a great deal, and have a greater understanding of ordinary concepts of Maths and Physics... good for the Engineering Brain (Student 2005 MS02).

'Cognitive conflict' had assisted in student cognition of the Mechanics concept being demonstrated:

This was a good session (walk the plank), the fact that it was done in front of everybody (Student MS05).

This was supported by the following:

I have learnt that doing experiments is a way to test whether theoretical info about a specific subject is true on my experiment, and If not so I need to

determine why my results differ and give a proper reason why! (Student 2005 MS06).

Students understood that 'cognitive conflict' and the reflection that goes with it was an important part of conceptual cognition.

The above is further evidence of greater concept formation and growing 'metacognition' (Schoenfeld, 1999) among the 2005 cohort due to a planned integration of FM into FS.

The study now turns to a further step in triangulation, namely an assumption that greater understanding of Mechanics concepts would lead to improved academic results in Mechanics 1. This is the subject matter of the next sub-section.

6.2.4. Triangulation by Mechanics 1 results

Statistical two-tailed t-tests for Means were performed comparing the Mathematics-with the Physics Matriculation results for each cohort. This was to establish if there was a correlation between the Mathematics results and the Physics results. On the assumption that there was no difference, a P value of less than 0.0001 means that the Mathematics result gave an indication of performance in Physics. If there was a low correlation then the Means have to be compared as the Physics result could be significantly lower or significantly higher. This sets a base line in the absence of a reliable pre-test which would be an indicator of students' conceptual understanding of Mathematics. This t-test merely gives an indicator of a trend and is not assumed to be generalisable beyond the conditions at CPUT.

The results are summarised in Table 6.2 below but the full t-test tables are contained in Appendices LL (1-4):

Table 6.2.two-tailed t-test paired two samples for means of Matriculation Maths vs Physics

	2002	2003	2004	2005
No of students	33	41	36	32
P (Maths vs Physics)	0.6397	0.000677	0.1370	0.0199
Mathematics Mean	46.0	50.3	46.7	50.9
Physics Mean	44.8	42.0	42.1	44.5

The P values in Table 6.2 indicate that there is a low correlation between students Matriculation results in Mathematics and Physics. The Means indicate that the Physics results tend to be significantly lower than the Mathematics results. Means should be used with caution, however, as they can be distorted with very high and very low results.

The next table, 6.3., contains results of applying the two-tailed t-test for Means to FM (MAR100) with FS (MIJ100); FS with Mechanics 1 (MIJ010) ; and MAR100 with Mechanics 1 (MIJ010) and its implications are discussed below:

Table 6.3.two-tailed t-tests for Means of FM vs FS; FS vs MIJ010; FM vs MIJ010

	2002	2003	2004	2005
No of students	39	48	42	38
FM vs FS	0.2542	3.64E -12	8.187E - 7	1.2 E - 6
No of students	27	36	20	28
FS vs MIJ010	1.9 E - 3	9.4 E - 3	1 E - 8	9 E - 6
No of students	27	36	20	28
FM vs MIJ010	1.6 E - 14	7.3 E - 18	2.2 E- 12	1.4 E - 9

The results from Table 6.2 indicate that from the 2003 to 2005 there is a higher correlation between FM results and FS results, demonstrating evidence of increased sequencing between the two subjects (even if it was unplanned or not properly planned).

That FM is a better indicator than FS of student performance in Mechanics 1 (Table 6.2) is consistent with the predictions of concept formation from learning theory, by which mechanics conceptualisation or reconceptualisation may be seen as arising through the use of underlying mathematical processes at a higher level (Sfard, 1991). Against the background of lack of integration, this comparison shows that the FM course in itself is based to a significant extent on Mechanics concepts. This is confirmation of evidence already presented from student focus groups in Chapters 4 and 5. that FM helped them with Mechanics 1.

With the above results in mind, an examination of the results of the Foundation students in Mechanics 1 may only be considered in relative terms, to the performance of the mainstream students to identify possible trends. These are examined in Table 6.4 below:

Table 6.4. Comparison of Foundation and Mainstream results in Mechanics 1.

Year	Mechanics mean (entire group) %	Mechanics mean (Foundation) %	Trend	Model
2002	48.3	40.4	Foundation significantly less	Fragmented
2003	46.9	48.4	Foundation marginally better	Fragmented and part-Sequenced
2004	42.5	43.3	Foundation marginally better	Fragmented developing to greater Sequencing
2005	43.8	50.9	Foundation significantly better	Fully Integrated

The results of Table 6.4 provides further confirmation carefully planned, integration of FM into FS, that takes into account the process of concept formation, is associated with greater understanding of Mechanics concepts. On the other hand, where the

process of concept formation is not adequately planned for and implemented, this is associated with no significant improvement in understanding or less understanding/a more 'surface' understanding.

The above results should also be seen from the point of view that the Foundation students would under previous circumstances have not been accepted into the Mechanical Engineering Programmes. To have achieved results that were on par with the mainstream shows that successful steps were taken to broaden access (CPUT, 2004) into Engineering. To have surpassed the mainstream results implies that successful steps are starting to be taken to improve pass rates overall, another of the key aims of the Foundation Programme (Jacobs & Jacobs, 2003).

6.2.5. Further challenges for integration of FM into FS

There are a number of areas that students identified, from the focus group discussions with each of the student cohorts, that needed further support. Each focus group member was given a few minutes to examine the topics in the questionnaire (Appendix A) and during the focus group discussions, could refer to it. The areas identified for further support are listed below:

1. Vectors (Student 2005 S02);
2. Geometry (Student 2005 S02);
3. Moments (Student 2004 S01);
4. Centre of Gravity (Student 2004 S02);
5. Lifting machines (Student 2004 S03);
6. Angular Motion (Student 2004 S04);
7. Forces (Student 2002 S01);
8. Conversion of units (Student 2002 S02);
9. Displacement, Speed and velocity, equations of motion (Student 2003 S01);
10. Flow rate (Student 2003 S01);
11. Calculating reaction in strength of materials (Student 2003 S02);
12. Work, energy, power (Student 2003 S03).

6.3. Vertical integration of Foundation Mathematics into S1 Mathematics

Evidence has been presented (see the summary in section 4.3.) that the conception of the FM course, of developing 'proceptual' ability (Sfard, 1991, Gray & Tall, 1994) did not match the design, which was based on a 'procedural' approach (Case &

Marshall, 2004). The report has also discussed evidence of the FM promoting student 'metacognition' in the way it was implemented while also demonstrating that the course was more based on Mechanics 1 than on the needs of preparing for S1 Mathematics (see section 5.5.). The redesign of the FM course, which in 2002 and 2003 included S1 Mathematics as part of the Foundation year would have provided a basis for aspects of 'structural abstraction' and 'awareness' to develop among students. In the absence of the S1 Mathematics course in 2004, the 'procedural' approach was expected to dominate, while in 2005 the introduction of complex numbers would point to an increase in 'structural awareness'. Overall, however, the 'procedural' approach was expected to be a dominant factor when considering the impact of the FM course with respect to its preparation for S1 Mathematics.

6.3.1. Triangulation by the Mathematics Focus group

Triangulation of this 'procedural' approach is demonstrated by the following quotation from a mainstream Mathematics lecturer when commenting on all the cohorts from 2002 to 2005 (he had lectured all of them at S2 Mathematics and higher):

I have looked at all the lists of students and yes there are some students who are doing very well, but there are also students who are doing very poorly. In all there is no difference between them and the performance of the mainstream students (Lecturer Maths L01).

On the one hand this indicated that the Foundation students had achieved at least the same level as the usual mainstream student, but on the other, and more crucially, that they had the same weak conceptual understanding of the requisite Engineering Mathematics.

This is further supported by the following:

Students have a problem when it comes to implementation of concepts such as curve sketching, wrong interpretation of Logs and Indices, they cannot manipulate formulae, they cannot relate to formulae and standard forms, they have a conceptual problem; they have to first understand the concept then develop an Engineering formula (Lecturer Maths L02).

While acknowledging that students who would not have gained entrance into the Mechanical Engineering under previous conditions were now performing at the same

levels of the mainstream students, the underlying problem of weak Mathematical conceptual understanding persists.

6.3.2. Triangulation by means of the 2004 questionnaire

By the time the 2004 questionnaire (Appendix B) was issued, two cohorts had had experience of the S1 level of study and even though the return rate was poor, the comments on open-ended questions are viewed as triangulation of trends referred to in the first paragraph under section 6.3 above.

Weak concept formation is exemplified by the following:

We need support on Mechanics and Mathematics (differentiation) (Student Q12002 S01).

Students identified the main section of S1 Mathematics that required 'structural awareness' namely, differentiation that required more support.

This is further supported by the following:

Yes, the S1 is one of the levels that must be done thoroughly, they must go deeper to summarise the S1 subjects (Student Q1 2003 S03).

This also points to insufficient use of mathematical concepts at higher levels (higher than pre-Calculus), with consequent weaker fundamental understanding.

Weak concept formation is further demonstrated students having to refer to their Foundation notes:

Now we are doing Hydraulics, I still refer to my work we did in Foundation (Student 2002 S03).

This shows that student understanding had reached the level of 'condensation' at best, and did not reach 'reification' as their understanding was still tied to the underlying mathematical processes.

6.3.3. Triangulation by statistical means

A two-tailed t-test comparing Means was performed to analyse possible trends in FM with S1 Mathematics results over the period of study. The results are given in Table 6.5 below:

Table 6.5. two-tailed t-test for Means FM vs S1 Mathematics

	2002	2003	2004	2005
No of students	34	45	20	29
P (FM vs S1 M)	1.04 E – 9	0.193	0.552	9.29 E - 5

From a first glance it appears that in relative terms the FM results in 2002 were a better indicator of S1 Mathematics results than in 2005. This was expected. The FM results in 2004, in the absence of doing S1 Mathematics in the Foundation year were not a good indicator of performance in S1 Mathematics, which was also expected. What was not expected was the results for the cohort of 2003. To make sense of this it is necessary to examine the relative performances of Foundation students and mainstream students. This is reflected in Table 6.6 below:

Table 6.6. Comparison of Foundation and mainstream results in S1 Mathematics

Year	S1 Mathematics Mean (entire group) %	S1 Mathematics Mean (Foundation) %	Trend	Model
2002	49.3	52.4	Foundation marginally better	S1 Maths in Foundation year
2003	61.4	66.4	Foundation significantly better	S1 Maths in Foundation year
2004	66.1	62.1	Foundation significantly worse	FM course on its own
2005	54.2	57.3	Foundation marginally better	FM course includes complex no's

The results for the 2003 cohort are consistent with predictions of improved performance due to a measure of concept formation in Mathematics that taking the S1 Mathematics course in the Foundation year would encourage. The reason for the relatively 'better' performance of the 2003 cohort over the 2002 one could be due to the many more practical problems and affective issues that the 2002 cohort faced. There is no equivalent evidence of strong concept formation for Mathematics for any of the cohorts, thus a significantly higher Mean translates only into marginally higher concept formation, which was what was predicted.

6.3.4. Other aspects of the impact of the FM course

Partial success at vertical integration is shown by the following:

It was useful with the Omnigraph to solve problems. Also in Maths 3 we did the same thing. Differentiation is something we are doing up to now ... I will definitely recommend the course because people who studied at Foundation level are stronger than those who went straight from matric to S1. They got awards (Student 2003 S01).

Students had gained some of the technical skills required for study within Mechanical Engineering and had developed a positive approach. Further evidence of a positive impact on student confidence is the following:

At the end of the Foundation Maths course I was confident before doing tests... I will recommend Foundation. It made us confident in our understanding (Student Q 2004 S04).

The 'confidence' was linked to examinations which is associated with a 'procedural' approach or 'surface' learning, however.

The FM course played its role in the Programme aim of broadening access:

I was not good at Maths at school so Foundation Maths closed that gap between high school and here... It was at that point but we didn't realise it at that time you come up with something you learnt in Foundation Maths (Student 2003 S02).

This also provides some evidence of aspects of 'structural awareness' having been achieved (the knowledge was not tied to the mathematical calculations underlying a concept). Taken together with all the other evidence provided above, this deeper conceptual understanding of Mathematics was episodic rather than generalised.

Further support for successful broadening of access to the field of Mechanical Engineering is given below:

Foundation Maths helped me because I came from a rural area (Student 2004 S05).

Broadening access without successful, generalised deeper learning of the Mathematics required in Engineering, will have limited impact on overcoming high first year failure rates and low throughputs.

6.3.5. Further challenges for the FM course

Areas which needed more support in FM are listed below. The main source is the response from the Mathematics focus group (Lecturer Maths L01) as the student focus groups only listed support for differentiation as a need. The central point made by the Mathematics focus group is a lack of conceptual understanding of mathematics:

1. Sine graphs;
2. Exponential and logarithmic curves;
3. Data handling and Curve sketching;
4. Logarithms;
5. Manipulation of formulae;
6. Relating to standard forms in differentiation and integration.

6.4. Summary of the main points of the impact of the Foundation Mathematics course

There were a number of administrative and technical problems that negatively affected student performance at the start of the Programme in 2002. Most of these appear to have been addressed, which assisted student cognition in the Programme. The conceptual and design flaws of the model of integration impacted negatively on student cognition of areas that they were struggling with, such as Mechanics

concepts. When steps were taken to overcome the conceptual and design flaws, student cognition in Mechanics concepts significantly improved and were consistent with the theoretical predictions of a 'fully' integrated curriculum. For vertical integration of FM, however, factors such as design flaws and 'polarity' led to weak conceptual understanding among Foundation students. This too, was consistent with the theoretical predictions of 'nested' integration.

A summary of the main points emerging from this Chapter is given below:

6.4.1. Affective issues and general problem areas

- In 2002 there were a number of practical problems that led to low motivation among students; negative feelings towards the course; there was a lack of students taking responsibility for their own learning; the Foundation Programme was seen as a 'barrier' rather than a 'gateway' to Mechanical Engineering (Jacobs *et al*, 2002).
- A number of steps were taken to address practical problems and student alienation (See 5.6).
- In the years of 2003 to 2005 a number of trends were observed, namely an increase in confidence among students; greatly reduced alienation; students were taking responsibility for improving their English ability; there was increased motivation among students; students increasingly regarded the Foundation Programme as a 'gateway' rather than a 'barrier' to Mechanical Engineering; students showed improved social skills such as being able to speak in front of large numbers of people; students indicated they were more able to make decisions as to whether they wanted to continue with Engineering or go elsewhere.
- Students felt that more should be done by lecturers to give feedback during the semester to improve learning; Studying in English for a second language speaker was noted as an ongoing challenge.

6.4.2. The impact of integration of FM into FS

- The results (such as in Table 6.3) provides confirmation that carefully planned, integration of FM into FS, that takes into account the process of concept formation, is associated with greater understanding of Mechanics concepts. On the other hand, where the process of concept formation is not adequately planned for and implemented, this is associated with no significant

improvement in understanding or less understanding/a more surface understanding.

- Successful efforts at integration of FM into FS is associated with assisting students to decide to continue with Mechanical Engineering. Students felt a sense of belonging and of becoming part of the Mechanical Engineering field, though successful attempts at integrating FM into FS.
- Many students in 2003 (about half the respondents to a questionnaire - Appendix C) still felt that FM did not support learning in other subjects, reflecting a fragmented integration of FM with FS, or at best a sequenced approach of FM with FS (see section 6.1.1).
- Students felt that more integration was necessary and identified areas for support: Vectors, Geometry, Moments, Centre of Gravity, Lifting machines, Angular Motion, Forces, Conversion of units, Displacement, Speed and velocity, equations of motion, Flow rate, calculating reaction in strength of materials, Work, energy, power.

6.4.3. The impact of integrating FM into S1 Mathematics

- FM results was a better indicator of student performance in Mechanics 1, than FS, indicating that the FM course was based more on Mechanics than on S1 Mathematics.
- The FM course was associated with improved motivation and confidence in Mathematics by the Foundation cohorts which are part of this case study.
- Students who had been through the FM course still displayed the same conceptual mathematics weaknesses as mainstream students.
- Some of the main areas where the conceptual weaknesses were identified are Sine graphs, Exponential and logarithmic curves, Data handling and Curve sketching, Logarithms, Manipulation of formulae, relating to standard forms in differentiation and integration.

6.5. Conclusion

This Chapter has set out the main findings of the impact of the FM course. It is thus appropriate to proceed to the conclusions and recommendations as a result of this Study. This is the subject matter of the next Chapter.

CHAPTER 7

RECOMMENDATIONS AND FURTHER RESEARCH

7.0. Introduction

This Chapter presents in consolidated form the framework for the Case Study as derived from the literature review. From this perspective the findings on the conception, design, implementation and impact of the contextualized model for Foundation Mathematics are summarized. This sets the platform for a discussion of recommendations and outlining of some of the areas for possible future research. The Chapter ends with brief concluding remarks.

7.1. The framework for the Case Study as derived from the literature review

This Study brings together the notion of academic literacy and approaches to learning as complementary theories to provide a framework for evaluation. Factors that should be considered when setting up and implementing an integrated curriculum mathematics course include:

General first year factors

Factors to be considered include: student emotional and social integration; developing requisite tertiary academic skills; student cognitive levels need to be considered and support mechanisms should be in place to enhance student cognition.

Factors from academic literacy theory

An integrated curriculum should consider factors such as 'natural affordance', 'affinity', 'validity', and 'polarity' of concepts being integrated.

Process of 'concept formation'

Student learning of concepts requires adequate time for students to progress from 'interiorisation' to 'condensation' to 'reification'; when students are working through problems relating to concepts they could progress from stages of 'recognition' to 're-presentation' to 'structural abstraction' to 'structural awareness'. The use of concepts in 'equivalent forms' aids not only cognition but could also specifically aid 'proceptual' ability that is essential for 'deep' learning. 'Procedural' approaches could hinder concept formation. The use of 'cognitive conflict' at an appropriate stage of learning

aids steps towards 'reification' of concepts. Conceptual 'formation' in the minds of students involves the use of the concept at a higher level.

Staffing needs

An integrated curriculum requires a staff trained in its facilitation.

7.2. The findings on the conceptualisation of the Foundation Mathematics course

The Case Study covered the period from 2002, when the programme was first implemented, to the end of 2005.

The Foundation Mathematics (FM) course was conceptualized as being part of a one year Programme preparing students for entry into a Diploma programme that was designed to lay the basis for Mechanical Engineering Technologists.

Horizontal integration

The Foundation EMS course was conceptualised as being the 'core' through which support for the cognition of Mechanics concepts was supposed to take place. Mathematical support for cognition of mechanics concepts was supposed to take place via integration with the Foundation EMS course. The Foundation model was flawed in that there was a lack of 'affordance', little 'validity', there was 'polarity' of different conceptual emphasis between EMS and other subjects, there was insufficient time in EMS for the basis of 'concept formation' and there was little scope for the requisite use of concepts at higher levels as Mechanics concepts were dealt with in a purely descriptive fashion in EMS. The result was a 'fragmented' model.

The conceptualization of integration by the lecturers and students

The lecturers' conception of the model evolved from a 'fragmented' approach (directly as a result of the conceptual flaws in the model) to a more 'fully integrated' approach over the period of the Case Study. Their development of a 'fully integrated' approach meant breaking from the original model. The students' conception of integration mirrored the evolution of that of the lecturers.

Vertical integration of the FM course

The conception of the FM course designers was of 'connected integration' while the FM lecturer was more of a 'nested' model. The FM course directly supported Mechanics concepts as part of its course content. The cohorts of 2002 and 2003 took S1 Mathematics as part of their Foundation year. This partially met the original conception of 'abstraction' required by the FM course designers. The cohorts of 2004 and 2005 only did pre-Calculus Mathematics as part of their Foundation year but the 2005 outcomes also included Complex numbers (which also partially met the conception of including 'abstraction' in the FM course). There was 'polarity' between the need to meet the requirements of pre-Calculus- based Mechanics while at the same time preparing students for Calculus-based S1 Mathematics.

Language support

The model limited support for Mechanics and mathematical concepts as Language support was conceived of as proceeding via EMS. This meant that Language support was given for 'materials' content at the exclusion of support for other subjects.

7.3. The findings on the design of the Foundation Mathematics course

The conceptual flaws of the model were reflected in its design aspects.

Language support

The language course was presented out of sync with the EMS course, resulting in confusion in the minds of the students. Only in 2005 was there a plan to include support for Mathematics as part of a new course design for Foundation Communications Skills.

Horizontal integration

The FS course was originally designed to be only six months long, which inhibited students' cognition of mechanics concepts. The Design of integration with respect to Mechanics concepts also evolved in line with the changed conception of the lecturers. 'Literal' equivalence between mainstream EMS and Foundation EMS also inhibited support for Mechanics concepts. A challenge for programme designers is how to maintain the integrity of courses while at the same time supporting concept formation that may be common to some or all of the courses.

Departmental support

Some of the findings of an earlier Evaluation were implemented but on the whole the findings were not carried over to all Foundation staff. The ongoing, annual internal departmental reviews were a strength of the Programme as they enabled self-reflection and some of the conceptual and design flaws were attenuated (through a form of 'action research'). Joint moderation by all Foundation lecturers of integrated assignments was essential for establishing or negotiating a minimum 'equivalence' necessary to support concept formation by 2005.

Vertical integration

The FM course had a 'procedural' design consistent with a 'nested' approach. The conceptual 'polarity' was carried over into the design. The findings suggest an extended S1 Mathematics course within the Foundation year would be a better model for meeting the FM course designers conception of greater 'abstraction' as a vehicle for student cognition.

7.4. The findings of the implementation of the Foundation Mathematics course

The conceptual and design flaws were carried over into the implementation phase of the FM course.

Student selection

The selected students for the Foundation programme did fit the required profile of the course designers, namely that they had met the minimum entry criteria for a Technikon (later Technical University) but not that of the Mechanical Engineering department . While the matriculation results indicated that most students struggled with Mathematics, they were relatively weaker in Physical Science. Most of the students did not have English as their first language.

Staff selection and training

None of the staff had received training in facilitating of an integrated curriculum. The training in tertiary level facilitation was not systematic. Both of these factors hampered student cognition. A Programme co-ordinator was only appointed in 2005. There was a possible mismatch of skills in facilitating courses with an Engineer being allocated to present the Computer Skills course instead of a subject like Foundation Science, where students would have derived greater benefit from his training and knowledge base.

Horizontal integration

As there was little integration around EMS, lecturers focused their attention around integrated assignments or projects. Except for the second half of 2005, attempts at horizontal integration did not support Mechanics 'concept formation'.

Vertical integration

The FM course did support both concepts in FS and Mechanics but 'out of sync'. The FM course promoted student 'metacognition' but was constrained by a 'procedural' approach adopted in the presentation of the course.

Practical problems

There were attempts to deal with student alienation, staffing problems, administrative obstacles, issues of class size as well as issues relating to tertiary level academic support.

7.5. The findings on the impact of the Foundation Mathematics course

General problem areas and affective issues

In 2002 students had low motivational levels and were frustrated at the number of practical obstacles they faced. From the middle of 2002, onwards there were attempts to address these problem areas resulting in greater confidence, a sense of social integration and students regarding the Foundation programme as a 'gateway' to Engineering rather than a 'barrier' to their advancement.

The impact of integration of FM into FS

As the lecturers evolved towards a 'fully' integrated conception and design, students increased their cognition of mechanics concepts, correspondingly. A number of areas were identified for future support by integration:

Vectors ; Geometry ; Moments ; Centre of Gravity ; Lifting machines; Angular Motion; Forces ; Conversion of units ; Displacement, Speed and velocity, equations of motion ; Flow rate ; calculating reaction in strength of materials ; Work, energy, power.

The impact of integrating FM into S1 Mathematics

The 'procedural' approach of the FM course resulted in 'weak' conceptual understanding of the requisite Mathematics, despite attempts at promoting student 'metacognition'. Nevertheless, students were more confident due to a progression, albeit limited, of their mathematical understanding. A number of areas were identified for future support by integration: Sine graphs; Exponential and logarithmic curves; Data handling and Curve sketching; Logarithms; Manipulation of formulae; relating to standard forms in differentiation and integration.

7.6. Recommendations

Based on the above findings, the following recommendations are made:

Recommendations on the conception of the FM course:

1. The content of the mainstream EMS course should be selectively retained in the Foundation Programme, perhaps being incorporated in the extended Manufacturing course;
2. EMS should not be considered as the 'core' for a fully integrated model for the Foundation Programme;
3. The content of the Mechanics 1 course lends itself better to be a 'core' course for a fully integrated model, however care should be taken not to force integration where there is little 'affordance' (Kress, 2000), 'validity' or where there is 'polarity' (Jacobs, 1989). Where these factors exist material is more usefully run in 'parallel' (Jacobs *et al*, 2002);
4. Integration should be set up in a manner that does not undermine the integrity of the constituent courses;
5. Relevant recommendations of the earlier evaluation (Jacobs *et al*, 2002) that have not been implemented, should be implemented (such as training of Foundation staff in facilitation of an integrated curriculum; training in facilitation of under-prepared students). Recommendations of evaluations should be made available to all Foundation staff in an accessible form;
6. The Foundation programme should ensure that all the CCFO's (Appendix KK1) are achieved as outcomes and that they are not only selectively used;

7. The 'polarity' of the FM course preparing students mainly for Mechanics1 at the expense of S1 Mathematics should be addressed. This may be partly achieved by ensuring that applications of differentiation are suitably chosen (such as optimisation, using differentiation and 'integration' with Mechanics concepts such as linear motion, simple harmonic motion);
8. Language support should be conceptualized to also include a focus on concepts that students have difficulty with, such as Mechanics concepts and certain concepts in Mathematics.

The recommendations on the design of the FM course

1. When planning and co-ordinating integration, due attention should be given to allow sufficient time for concept formation and that the relevant concepts are indeed being assessed in the assignments/projects. This would ensure that the use of 'cognitive conflict' (Hubbard, 1997) to enhance concept formation is more cognitive than conflict. Integrated practicals should be considered to support the areas identified in 7.5 above with respect to Mechanics and Mathematics ;
2. Foundation lecturers should jointly set up evaluation criteria in advance to ensure a minimum of equivalence (Goodsen- Espy, 1998) of understanding over concepts that may overlap multiple disciplines. Joint moderation of integrated assignments would assist in ensuring that the notion of equivalence is realised;
3. Attention should be given to concept formation over literal equivalence (Jacobs *et al*, 2002) such as having to do the same assessments at the same time as the mainstream courses;
4. Timely, immediate feedback to students would enhance concept formation (such as through 'walk the plank' exercises) ;
5. Effective pre-tests (at the start of the Foundation year) should be used to establish areas of weak concept formation in respective subject areas;
6. 'Muddy' cards are a useful mechanism to assist in gauging degrees of concept formation among students;
7. There should be a mechanism of evaluation of the Foundation Programme that is part of the finalising of the new model for 2007 (Appendix QQ) as well as part of its ongoing implementation;

8. In-depth assessment (Sazhin, 1999) should be considered to replace examinations (such as including aspects where students have to comment on their answers) ;
9. The FM course should be re-designed to reduce the broad sweep of its content to focus more of developing student 'metacognitive' skills but with fewer concepts (a recommendation from the Mathematics focus group). This should consider the areas on Sine graphs, Exponential and logarithmic curves, Data handling and Curve sketching, Logarithms, Manipulation of formulae, relating to standard forms in differentiation and integration;
10. Creative use of linking Mathematics to the attitudes of Mechanical engineering should be considered – such as 'Does it work?' and 'Can you calculate that it will work?'; 'Can you draw something that will work?' ; 'Is it strong enough?' and 'What are the dimensions that make it strong enough?'; 'Can you calculate if it is strong enough?' (all recommendations from lecturer Main L04); 'What do you need to know to produce something?'; 'Formulae are tools- what formulae do you need?', or 'Can you create a formula or adapt an existing one to suit the problem?' (all recommendations from Main L03);
11. Greater attention should be given to the broad first year issues that entry level students face, such as arranging activities that socialise them into Mechanical Engineering at an earlier date – such as a breakaway camp and Engineering company site visits. These should be considered for mainstream students as well. The positive activities around enhancing student study skills should be continued;
12. The language support should be synchronised with the presentation of the relevant concepts in other subject areas;
13. Mathematics support should be synchronised with the presentation of concepts in Mechanics but in a manner which does not undermine the needs for conceptual development in Mathematics.

Recommendation on the implementation of the FM course

1. With the limited resources available, due attention should be given to ensure that the Foundation class size does not inhibit student cognition;
2. There should be an appropriate match of skills of lecturers with the needs of the outcomes of the Foundation Programme (such as the use of available experienced Mechanical Engineers with core aspects instead of support courses such as Introduction to Computers);

3. Administrative issues such as Foundation students not receiving progress reports during the year should be attended to;
4. Student selection should be extended to the mainstream students who need support but who, under the current model, are excluded from the Foundation Programme;
5. Tutors for the respective subject areas should receive appropriate training and should have the necessary conceptual understanding in the relevant subject area they are expected to work in;
6. There should be ongoing discussion and planning of which concepts will be supported and when. Consideration should be given to including themes around which support for several concepts may be given.

7.7. Areas for future research

The following areas have been identified for future research:

Conception of the FM course

1. This Case Study has focused on a particular locus, namely a department within an University of Technology in the Western Cape province in South Africa. Further research is needed to assess how generalizable the findings are;
2. The question still arises, as it did in 2002, as to whether students who meet the entrance requirement for a subject should be compelled to take the respective Foundation subject (Jacobs *et al*, 2002). Research into this question may shed light on ways of more effective use of resources;
3. How does the development of a learning approach impact on learning styles (Case & Fraser, 2002) of students;
4. How widely can the theory of 'structural abstraction' (Cifarelli, 1988) be generalised in contexts beyond Mathematics;

Design of the FM course

1. What is an appropriate balance between integration with other subject areas and the disciplinary requirements of a discipline/subject? Linked to this is the question of to what extent the demands of mathematical preparation for a pre-Calculus Mechanics course while meeting the abstract demands of Engineering Mathematics;

2. Which factors contribute to student alienation and what are appropriate mechanisms of attenuating or eliminating these? How effective are attempts to alleviate student alienation?

Implementation of the FM course

1. An appropriate mechanism to identify students with 'weak' conceptual understanding and who could be classified as being 'at risk', needs to be developed;
2. The most appropriate class size that, within the limited resources available, is most conducive to student cognition, needs to be investigated.

Impact of the FM course

There should be an ongoing mechanism to effectively evaluate the intended impact of the FM course and indeed of the entire Foundation Programme.

7.8. Conclusion

The main thesis of this Study has been validated against the background of existing theory: There were several conceptual and design flaws in the Programme model which inhibited student cognition of mechanics and of mathematical concepts requisite for the Mechanical Engineering Diploma programme (MDIPME). Only to the extent that there was a break from the model, that is, from what was effectively a 'fragmented' approach, towards a 'fully' integrated approach did student cognition of Mechanics concepts improve.

The findings of this Case Study are consistent with the use of academic literacy theory together with learning approach theory. The findings show that learning approach theory is also an elaboration of academic literacy theory by giving insight into its concepts such as 'affordance' (Kress, 2000), 'validity' and 'polarity' (Jacobs, 1989). The consistency of the findings of this Study provides a cross-validation of the use of academic literacy theory together with learning approach theory.

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Questionnaire issued in 2005 (to students of Foundation cohorts 2002, 2003, 2004 and 2005)

STUDENT EVALUATION OF FOUNDATION COURSE [Oct 2005]

Due to the pioneering work of the first 3 years of the Foundation programme the state has agreed to fund it. We are in the process of redesigning the course and would like your input. This is very important if we are to improve the course and learn from our strengths and weaknesses. The purpose of this questionnaire is to establish your views of the different aspects of the integration of Foundation mathematics into the Foundation Science course. Please tick the appropriate box

[✓] and provide the information required:

Fill in the year that you completed the Foundation Course:.....

A. Foundation Maths was integrated into Foundation Science via (draw a circle around one or more of the following)

- | | | |
|-------------------------------------|-----------------|-----------------------|
| Integrated project | lab experiments | manufacturing project |
| Examples in class
(Specify)..... | none of these | other |

Write a short paragraph about what you understand by the phrase: "integration of Foundation Mathematics into Foundation Science".....

.....

....

.....

....

.....

....

.....

....

.....
 ...
 B. Read the statements below and respond by making a tick [✓] in the relevant box of your choice. Return the completed questionnaire to the facilitator at the end of the session.

	Strongly agree	Agree	Don't know	Disagree	Strongly disagree
1. The Foundation Mathematics (FM) course has improved my understanding of the basics of the subject.					
2. The Foundation maths course prepared me adequately (sufficiently) to cope with S1 Mathematics					
3. I felt comfortable enough to approach the lecturers when I did not understand the work.					
4. The Mathematics lectures have assisted me in understanding other subjects better.					
5. The Foundation Mathematics course gave me lots of practice with mathematics procedures/techniques					
6. I soon forgot these procedures/techniques					
7. In the Diploma course I still made many of the Mathematical mistakes I used to make before I took the Foundation Maths course					
8. The Foundation Maths course helped me learn to put in numbers and formulae from a 'word problem' from Foundation Science					
9. The overall Foundation Maths course workload was too much compared to S1 subject workload					
10. Foundation Maths course helped me learn to describe in words what an equation/formula meant from Foundation Science [FS]					
11. Integration of the Foundation Maths course with Foundation Science helped me work out new problems that I had not yet seen or come across before					
12. Foundation Maths, on its own, not linked to Foundation Science, helped me learn how to justify the working of my answer					
13. Foundation Maths, on its own, not linked to Foundation Science, helped me learn how to interpret or make sense of a new problem in Foundation Science					
14. Foundation Maths, on its own, not linked to Foundation Science, helped me learn how to work out what the implications were of my answer to a problem in Foundation Science					
15. Foundation Maths, on its own, not linked to Foundation Science, helped me learn to make a theoretical model of a problem in Foundation Science			✓		

16. Foundation Maths, on its own, not linked to Foundation Science helped me learn to make comparisons between 2 or more possible approaches and to select an appropriate one					
17. Foundation Maths, on its own, not linked to Foundation Science, helped me learn how to get an overall (global view) of a problem, a possible method of solution and to critically examine the answer itself					
18. Foundation Maths integrated with Foundation Science, helped me learn how to interpret or make sense of a new problem in Foundation Science					
19. Foundation Maths integrated with Foundation Science, helped me learn how to work out what the implications were of my answer to a problem in Foundation Science					
20. Foundation Maths, integrated with Foundation Science , helped me learn to make a theoretical model of a problem in Foundation Science					
21. Foundation Maths integrated with Foundation Science, helped me learn to make comparisons between 2 or more possible approaches and to select an appropriate one					
22. Foundation Maths integrated with Foundation Science, helped me learn how to get an overall (global view) of a problem, a possible method of solution and to critically examine the answer itself					
23. There was not enough integration of Foundation Maths into Foundation Science					
24. The skills I learnt through integration of Foundation Maths with Foundation Science I could apply in my diploma course					
25. There should be less integration of Foundation Maths into Foundation Science					
26. Proficiency in English is not a requirement for academic success.					
27. The lecturer for the Foundation Science course was well trained					
28. The skills learnt from integration of Foundation Maths into Foundation Science helped me achieve the outcomes for the Diploma courses					
29. The achievement of the outcomes of the Foundation programme will contribute to the outcomes for the Diploma/Degree					
30.The lecturer for the Foundation Maths course was well trained					
31. The tutors for the course are well trained and helpful					
32. The level of difficulty of the Programme is appropriate for its level					
33. In the programme I was encouraged to be					

culturally sensitive					
34. The Programme helped me appreciate differences in gender.					
35. The programme helped me appreciate differences in religion and customs					
36. Adequate time was given to lab work					
37. Adequate time was given to extramural work outside of the classroom					
38. laboratory sessions are a valuable part of the Foundation programme					
39. Lecturing and course work were well sequenced for integration of Foundation Maths into Foundation Science					
40. I was free to question the lecturers					
41. I was scared to question the lecturers					
42. Weighting of integration of Foundation Maths into Foundation Science should increased					
43. At school teachers could not explain the Maths					
44. At school classes were overcrowded					
45. At school some topics were not taught					
46. At school teachers did not give personal attention					
47. At school we often had new teachers					
48. At school we had few or no textbooks					

C.

Fill in the following tables and list the topics in the order indicated

Course	Outcome	Not competent	Fair	Competent
Foundation Science	Units & Conversions			
	Atomic structure			
	Gas laws			
	Graphic addition of vectors			
	Resolution of vectors into rectangular components			
	Displacement			
	Speed			
	Velocity			
	Acceleration			
	Equations of motion			
	Graphs of motion			
	Equilibrium			
	Free body diagrams			
Momentum				

List the above topics in order of most difficult to least difficult

Course	Outcome	Not competent	Fair	Competent
Mechanics MIJ 010	Forces			
	Moments			
	Centres of gravity			
	Linear motion			
	Angular motion			
	Centripetal force			
	Friction			
	Work, power, energy			
	Momentum and impulse			
Lifting machines				

List the above topics in order of most difficult to least difficult

Course	Outcome	Not competent	Fair	Competent
Foundation Mathematics MAR100	Indices			
	Logarithms			
	Use of calculator			
	Sine and cosine graphs			
	Exponential and logarithmic curves			
	Solutions of linear equations			
	Radian measure			

	Solution of quadratic equations			
	Basic geometry			
	Ratios and proportion			
	Areas and volumes			
	Data handling and drawing of graphs			
	Basic trigonometry			
	Graph sketching			
	Velocity and acceleration			
	Understanding the parabola			

List the above topics in order of most difficult to least difficult

Course	Outcome	Not competent	Fair	Competent
Foundation Communication MKD100	Drawing a table			
	Report writing			
	Essay writing			
	General communication skills			

List the above topics in order of most difficult to least difficult

D.

Answer the following questions by writing in your opinion in the space provided. If you need more space, attach a page with your comments, clearly showing which section and which question you are referring to.

1. What were the problems around integration of Foundation Maths into FS?

a) sequencing of lectures before and after?

b) Was the mentoring consistent?

- c) Were the course materials adequate for integration of Fm into FS
- d) Was the use of the library encouraged?
- e) Was the use of the internet encouraged?
- f) Were the technical terms in FM and FS explained well enough?
- g) Did your understanding of concepts change through having gone through integration exercises of FM into FS
- h) Too little integration? What more is needed?
- i) How well were you oriented towards integrated projects or assignments?
- j) Was there enough equipment for integration exercises?
- k) Was the support adequate for integration?

2. What skills did you feel you gained from integration of FM into FS?
3. How can integration be improved? What about the relation to Mechanics?
4. Has your self-confidence increased through these integrated projects, to help you more confidently handle the Diploma coursework and challenges?
5. Have you learnt to be more critical of your own work due to the integration of Foundation Maths into Foundation Science?
6. Did you gain anything from feedback from your integrated assignments/projects? Were there any negative points about the feedback?
7. What was your experience of group work and what did you learn?
8. What impact did the fact that the work was conducted in English and that your 2nd or third language is English? What can be done to overcome it?
9. Do you think you learnt more through integration than lectures?
10. Was there scope for the development of leadership skills in integration?
11. If you had been involved than more than one integrated project of Foundation Maths into Foundation Science, what was your experience on the 2nd and other occasions?
12. Was there scope for independent learning?

13. What did you learn about accuracy of answers [only one vs a range of possible answers]

14. What about the differences between theory and practice?

15. What improvements can be made to integration?

16. Which concepts from Mechanics /Foundation Science should be more explicitly supported from a Foundation Maths point of view?

17. How much time do you spend travelling to and from campus?

18. Where do you live [what sort of accommodation] how does this affect your studies?

19. When taking a maths test (before the Foundation Maths) course I was :

Cold sweaty short of breath confident challenged

Strong capable energetic clever in control

None of the above

20. When taking a maths test (towards the end of the Foundation Maths) course I was :

Cold sweaty short of breath confident challenged

Strong capable energetic clever in control

None of the above

Appendix B
Questionnaire issued in 2004

STUDENT EVALUATION OF FOUNDATION COURSE

Due to the pioneering work of the first 3 years of the Foundation programme the state has agreed to fund it. We are in the process of redesigning the course and would like your input. This is very important if we are to improve the course and learn from our strengths and weaknesses. The purpose of this questionnaire is to establish your views of the different aspects of the Foundation course. Please tick the appropriate box [✓] and provide the information required:

Fill in the year that you completed the Foundation Course:.....

A. Read the statements below and respond by making a tick [✓] in the relevant box of your choice. Return the completed questionnaire to the facilitator at the end of the session.

	Strongly agree	Agree	Disagree	Strongly disagree
1. The foundation course should be done by all the Mechanical Engineering students.				
2. The Foundation Mathematics lectures have improved my understanding of the subject.				
3. I felt comfortable enough to approach the lecturers when I did not understand the work.				
4. The Mathematics lectures have assisted me in understanding other subjects better.				
5. The Foundation drawing course sufficiently improved my understanding and skill in the subject* [2003 students only]				
6. The Physics lectures have helped me improve my understanding of the subject.				
7. The foundation subjects are too easy.				
8. The Computer skills lectures have improved my computer skills.				
9. The overall course workload was too much				
10. Engineering materials and science lectures have improved my understanding of the subject.				
11. The language lectures have improved my English language skills.				
12. The foundation course does not offer enough				

support to students who are struggling to cope with the work.				
13. Proficiency in English is not a requirement for academic success.				
14. I can make the link between the Foundation and Diploma courses				
15. The Foundation programme helped me achieve the outcomes for the Diploma courses				
16. The achievement of the outcomes of the Foundation programme will contribute to the outcomes for the Diploma/Degree				
17. The Foundation course has helped me to work towards a B-Tech				
18. The tutors for the course are well trained and helpful				
19. The level of difficulty of the Programme is appropriate for its level				
20. In the programme I was encouraged to be culturally sensitive				
21. The Programme helped me appreciate differences in gender.				
22. The programme helped me appreciate differences in religion and customs				
23. Adequate time was given to lab work				
24. Adequate time was given to extramural work outside of the classroom				
25. laboratory sessions are a valuable part of the Foundation programme				

Answer the following by writing your response in the space/s provided.

Comment in as much detail as possible with the aid of the table below on the positive points and points that need improvement with regard to how the Foundation course prepared you [or did not] for the S1 courses and other courses within the MDIPME.

Course	Outcome	Not competent	Fair	Competent
Drawing1-MMD 010	Free hand sketching			
	Isometric view			
	Orthographic views			
	Geometric constructions			

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Computer Skills-MCPR010	MSWord Formatting			
	Internet			
	MS Excel: numbering, formulae, graphs, charts			
	Power Point			

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Foundation Science	Units & Conversions			
	Atomic structure			
	Gas laws			
	Graphic addition of vectors			
	Resolution of vectors into rectangular components			
	Displacement			
	Speed			
	Velocity			
	Acceleration			
	Equations of motion			
	Graphs of motion			
	Equilibrium			
	Free body diagrams			
Momentum				

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Manufacturing MIE 010	Steel types			
	Fasteners			
	Micrometer			
	Welding			
	Drilling			
	Lathe			
	Hand tools			
	Safety precautions			

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Mechanics MIJ 010	Forces			
	Moments			
	Centres of gravity			
	Linear motion			
	Angular motion			
	Centripetal force			
	Friction			
	Work, power, energy			
	Momentum and impulse			

	Lifting machines			
--	------------------	--	--	--

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Foundation Mathematics MAR100	Indices			
	Logarithms			
	Use of calculator			
	Sine and cosine graphs			
	Exponential and logarithmic curves			
	Solutions of linear equations			
	Radian measure			
	Solution of quadratic equations			
	Basic geometry			
	Ratios and proportion			
	Areas and volumes			
	Data handling and drawing of graphs			
	Basic trigonometry			
	Graph sketching			
	Velocity and acceleration			
Understanding the parabola				

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Mathematics MARB 10	Indices and logarithms			
	Use of calculator			
	Sine and cosine graphs			
	Exponential and logarithmic curves			
	Solutions of equations			
	Radian measure			
	Guassian elimination			
	Matrix theory			
	Differentiation			
	Binomial theorem			
	Implicit differentiation			
	Logarithmic differentiation			
	Graph sketching			
	Velocity and acceleration			
Integration				

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Foundation Communication MKD100	Drawing a table			
	Report writing			
	Essay writing			
	General communication skills			

I should have learnt.....in the course but did not

Course	Outcome	Not competent	Fair	Competent
Communication skills MKD010	Understanding exam questions			
	Answering a comprehension			
	Giving answers			
	Understanding instructions			
	Identifying keywords			
	Understanding grammar			

I should have learnt.....in the course but did not

What did you like about the course?

[please respond about each of the courses you took, where possible, see above-what helped a lot?]

When doing S1, is support needed for any of the subjects? Motivate your answer

General comments?

Please feel free to use the back of the page for your extra comments

STUDENT EVALUATION OF FOUNDATION COURSE

The purpose of this questionnaire is to establish your views of the different aspects of the Foundation course of the 1st semester 2003. Please tick the appropriate box

[✓] and provide the information required:

A. Read the statements below and respond by making a tick [✓] in the relevant box of your choice. Return the completed questionnaire to the facilitator at the end of the session.

	Strongly agree	Agree	Disagree	Strongly disagree
1. The foundation course should be done by all the Mechanical Engineering students.				
2. The Foundation Mathematics lectures have improved my understanding of the subject.				
3. I felt comfortable enough to approach the lecturers when I did not understand the work.				
4. The Mathematics lectures have assisted me in understanding other subjects better.				
5. The Physics lectures have helped me improve my understanding of the subject.				
6. The foundation subjects are too easy.				
7. The Computer skills lectures have improved my computer skills.				
8. The overall course workload was too much				
9. Engineering materials and science lectures have improved my understanding of the subject.				
10. The language lectures have improved my English language skills.				
11. The mathematics lectures were interesting.				
12. The language lectures were interesting.				
13. The Engineering materials and science lectures were interesting.				
14. Computer skills lectures were interesting.				
15. The physics lectures were interesting.				
16. The foundation subjects are too difficult.				
17. The foundation course does not offer enough support to students who are struggling to cope with the work.				
18. Proficiency in English is not a requirement for academic success.				

Answer the following by writing your response in the space/s provided.

Mention the weaknesses in the Foundation course

What did you like about the course?

What suggestions do you have for improving the course?

Would you recommend this course to other potential students? Give motivation for your answer.

General comments?

Please feel free to use the back of the page for your extra comments

Questionnaire issued to lecturers in 2006 on skills needed and on the shortcomings

Questions to the Mathematics-Communication skills cluster

Mathematical thinking skills and ex-Foundation students:

The focus of this questionnaire is to explore ways in which the Foundation Mathematics course can be improved. We need to examine a number of factors and request your assistance in our common striving to improve the success rates of our students at Diploma level. The data gathered is confidential and will be strictly for the purposes of evaluating the Foundation Mathematics course and will not be used in any other way.

Please answer the questions as frankly as possible. The responses will also be used to develop focus interviews.

Due date: Please return this to me or Raileen by the 23rd June 2006.

Do you agree to take part in this research:

Yes	No
-----	----

Subject
Subject Code

Subject
Subject Code

1. What Mathematical thinking skills are required by the successful student in your subject or for the Diploma as a whole?

2. Which mathematics thinking skill is the one that students are mostly struggling with? Why?

3. Comment about the relative performance of the ex-Foundation and Mainstream students with respect to the thinking skill that students appear to be struggling with [identified in point 2 above].

4. What do think is an example of a 'best practice' to overcome the difficulty mentioned in point 2 above?

5. Have a look at the attached list of ex-Foundation students. Comment on the relative abilities and performance of ex-Foundation students with those of the mainstream Diploma students on:
 - a. ability to apply Mathematical skills learnt

 - b. speed of retrieving information

 - c. integrated knowledge base

d. depth and breadth of learning

e. attitude to their Diploma studies

6. What is the most striking positive point/s about the ex-Foundation students?

7. What is the most striking negative point/s about the ex-Foundation students?

8. Was language an obstacle to the developing of the required thinking skills?

9. Did the Foundation programme and the Foundation Mathematics course in particular have any other impact, not mentioned above?

10. As far as it is possible to identify trends among the students, please fill in the table below Refer to the attached table of explanations to assist you. Please enter a number 1-5 according to the following in each of the spaces below:

1-Strongly agree, 2-Agree, 3-Disagree, 4-Strongly disagree ,5-Don't know.

	Essential	Problem areas	Ex-Foundation excel	Ex-Foundation struggle	Mainstream excel	Mainstream struggle
Factual knowledge						
Information transfer						
Justify and interpret						
Comprehension						
Application in new situation-Mathematical						
Application in new situation-other						
Implications, conjecture, comparisons						

Routine procedures						
Evaluation; judgement; creatively restructure						
Generalising ; synthesizing;						
abstraction ; classifying;						
forming conceptual entities;						
generic generalizations;						
coping with disequilibrium;						
imagery;						
reflectivity						
transition						
reversability						
refined intuition						
algorithmic activity;						
recording knowledge						
representation						
terminology						

:

11. Which engineering concepts do mainstream students struggle with?

12. Which engineering concepts do ex-Foundation students struggle with?

13. Which engineering concepts do Ex-Foundation students excel at relative to the Mainstream students?

14. Do you think the Foundation programme should be continued? [Explain your answer]

NB Please attach a copy of a final evaluation with memorandum as well as an integrated assignment with assessment criteria.

Peninsula Technikon
Year 0
Basic Mathematics and Science
For Mechanical Engineering

COURSE OUTLINE

This course is to give basic preparation in Mathematics and Science so that students would be ready to proceed comfortably into the S1 course. So we will explore basic ideas [concepts] of Mechanical Engineering and the mathematical calculations related to this. If you have been struggling to understand or cope with Mathematics or Science, YOU are in the right place. Don't be shy to try out your own ideas, ask questions, or even make mistakes. Scientists make mistakes all the time. The point is to *learn* from this. Thomas Edison, the inventor of the light bulb, was asked about the many mistakes he made. He was trying to find a way to store electricity in a container. After he tried and did not succeed 20 000 times, Edison said: " Well, at least now I have discovered 20 000 new ways how NOT to store electricity."

Your own interests in Science will be taken into account when we explore the basics of Science. The main emphasis of the course is for you to develop a scientific method, so that, whichever branch of Science you decide to go into, you will have a basic approach and level of understanding, to make a good start.

Please note: This is a pilot course, so the course content that is listed below could be changed, depending on the progress we make. We will try our best to complete all the topics listed below.

Course Content:

MECHANICS

1. Vectors:
 - 1.1 Introduction
 - 1.2 Vectors in a plane or flat surface
 - 1.3 Simple addition of vectors
 - 1.4 Vectors, as the sum of 2 other vectors at 90° to each other
 - 1.5 Exercises on vectors

2. Motion in a straight line [Rectilinear]
 - 2.1 Motion
 - 2.2 Distance and Displacement
 - 2.3 Speed and Velocity
 - 2.4 Acceleration
 - 2.5 Graphs of motion
 - 2.6 Free falling bodies

3. Momentum

- 3.1 Momentum for objects traveling in a straight line – introduction
- 3.2 Conservation of momentum
- 3.3 Impulse
- 3.4 Elastic and non-elastic collisions [that is, where the colliding objects do not ‘stick together’, or they do ‘stick together’]

INTRODUCTION TO CHEMISTRY

4. Atomic structure

- 4.1 Introduction
- 4.2 Bonds between atoms of the same substance and between different structures
- 4.3 Properties of some interesting substances, of use in Engineering, and more broadly

5. Gases

- 5.1 Introduction
- 5.2 Thermal [heat] properties
- 5.3 Ideal gases

MORE ON MECHANICS

6. Overview of other important concepts [ideas] in mechanics

- 6.1 Forces
- 6.2 Moments
- 6.3 Centre of Gravity
- 6.4 Friction
- 6.5 Work and Power
- 6.6 Potential and Kinetic Energy
- 6.7 Angular Motion
- 6.8 Centrifugal and centripetal force
- 6.9 Simple lifting machines
- 6.10 Torque

BASIC MATHEMATICS

- 1. Accuracy [including rounding off of numbers]
- 2. Introduction to the calculator
- 3. Fractions ; simultaneous equations.
- 4. Working with formulae and practice in making different terms the subject of the formula [or solving for different things such as time , speed, or velocity, distance, displacement, etc]
- 5. Indices, simple and in combinations
- 6. Conversion of Units
- 7. The Theorem of Pythagoras
- 8. Simple trigonometry [right angled triangles and directions]
- 9. Functions
- 10. Simple equations
- 11. Quadratic equations [$ax^2 + bx + c = 0$]
- 12. Ratios and percentages
- 13. Straight line and other graphs [finding new information from the graphs]

14. Constructing graphs from data [information] – finding more information from graphs
15. Inequalities and shading of areas.
16. Areas and volumes
17. Finding the centre point for simple figures
18. More on trigonometry [including the Sine Rule and Cosine Rules; radians]
19. The parabola [including the completion of the square – note that the parabola and quadratic equations are directly related]
20. The hyperbola
21. Simple examples of the Simpson's Rule
22. Radian Measure

Consultation times: Fridays between [1- 2 pm] Please note for any other times, try to make arrangements with me beforehand.

Evaluation: This will be finalized in due course. It will be made up of attendance; class assignments; Lab work; weekly tests and a final test. Attendance at all sessions is compulsory. An attendance register will be taken at each session.

Lecturer: Shaheed Mahomed Room 0115 1st Floor , Mechanical Engineering
22.02.02

**Peninsula Technikon
Foundation
2004**

**Basic Mathematics
For Mechanical Engineering**

Course Outline

This course is to give basic preparation in Mathematics so that students would be ready to proceed comfortably into the S1 course. So we will explore basic ideas [concepts] of Mechanical Engineering and the mathematical calculations related to this. If you have been struggling to understand or cope with Mathematics, **YOU** are in the right place. Don't be shy to try out your own ideas or ask questions, or even to make mistakes. Scientists make mistakes all the time. The NASA space shuttle blew up on re-entry into the earth's atmosphere, despite the work of the most advanced scientists on earth. [There are many other examples that one can think of.] The point is to *learn* from the mistakes. Thomas Edison, the inventor of the light bulb, was asked about the many mistakes he had made. He was trying to find a way to store electricity in a container. After he tried and did not succeed 20 000 times, Edison said: " Well, at least now I have discovered 20 000 new ways how NOT to store electricity."

Your own interests in Science and Mathematics will be taken into account when we explore the basics in this course. The main emphasis is for you to develop a scientific method, so that, whichever branch of Science you decide to go into, you will have a basic approach that is good enough for you to make a good start.

Please note: This is the first time that the Foundation Mathematics course runs over a full year. The course content may be changed, depending on the progress that we make. We will try our best to complete the listed topics.

NOTE: STUDENTS MUST PASS ALL FOUNDATION SUBJECTS, INCLUDING MATHEMATICS, IN ORDER TO BE ADMITTED INTO THE FULL S1 COURSE.

Lecturer: Shaheed Mahomed ext 6560 mahomeds@pentech.ac.za **Moderator:** D Gabriels

Recommended Reading:

PreCalculus: Watson et al [on short loan in the library] ; Please check the library for other texts on Foundation Mathematics.

Course content:

1. Accuracy [including rounding off of numbers]
2. Introduction to the calculator
3. Real numbers
4. Conversion of units
5. Fractions; simultaneous equations

6. Working with formulae and practice in making different terms the subject of the formula [or solving for different unknowns such as time, speed, velocity, distance, displacement, etc]
7. Indices, simple and in combinations
8. Logarithms
9. The Theorem of Pythagoras
10. Simple trigonometry
11. Functions
12. Simple equations
13. Quadratic equations [$ax^2 + bx + c = 0$]
14. Ratios and percentages
15. Straight line and other graphs [finding information from the graphs]
16. The parabola [including the completion of the square – note that the parabola and quadratic equations are directly related]
17. Constructing graphs from data – finding out more information from graphs
18. Tangent lines
19. Introduction to limits
20. Inequalities and shading of areas
21. More on trigonometry [including the Sine and Cosine rules]
22. The Sine graph
23. Areas and volumes
24. Finding the centrepoinets of simple figures
25. The hyperbola
26. Radian measure
27. Simple examples of Simpson's rule
28. Introduction to differentiation
29. Introduction to integration

Consultation times: Thursdays between 1-2pm. For any other times, please make arrangements with me beforehand.

Evaluation:

Attendance at all sessions is compulsory. Absences may result in evaluations 2 & 6 results being reduced.

Semester 1

Evaluation 1	Midterm test	15%	17 th March
Evaluation 2	Ongoing tests	12.5%	
Evaluation 3	Integrated project part 1	7.5%	
Evaluation 4	Semester 1 final test	15%	2 June

Semester 2

Evaluation 5	Midterm test	15%	tbd
Evaluation 6	Ongoing tests	12.5%	
Evaluation 7	Integrated project part 2	7.5%	
Evaluation 8	Semester 2 final test	15%	tbd

MAR100 November Evaluation 3 Nov 2004

Instructions:

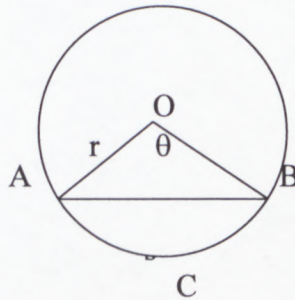
1. Answer all questions
2. Start with those you find easier and then return to the rest.
3. smile ☺

100% = 60 Marks

Question 1

In the figure:

$0^\circ \leq \theta \leq 360^\circ$
 $s = \text{arc } ACB$
 segment = ABC
 sector = AOBC



- 1.1 If $r = 2.1\text{m}$ and $\theta = 125^\circ$ calculate the area of AOBC [4]
- 1.2 If $r=2.58\text{m}$ and $s = 4.24\text{m}$, calculate the area of ABC [4]
- 1.3 If $\theta=58^\circ$ and area ABC = 48cm^2 , calculate r [4]
- 1.4 Write the following angles in terms of π : 45° ; 30° ; 160° ; 60° [2]

SUBTOTAL 14

Useful formulae:

Area = $\frac{1}{2} r^2 \theta$

Area = $\frac{1}{2} r^2 (\theta - \text{Sin}\theta)$

$\theta = s/r$

[NB: Remember to switch your calculator to radian mode where appropriate]

Question 2

- i) if $\log k = 0.35$, find k [2]
- ii) if $e^x = 2.1$ find x [2]
- iii) if $\ln z = 1.92$ find z [2]
- iv) simplify without the use of a calculator: $\log_{\frac{1}{5}} 25$ [3]

SUBTOTAL 9

Question 3

a) If $W = RT \ln\left(\frac{V}{V_o}\right)$, make V the subject [4]

b) The natural frequency f_n of a body under simple harmonic motion is

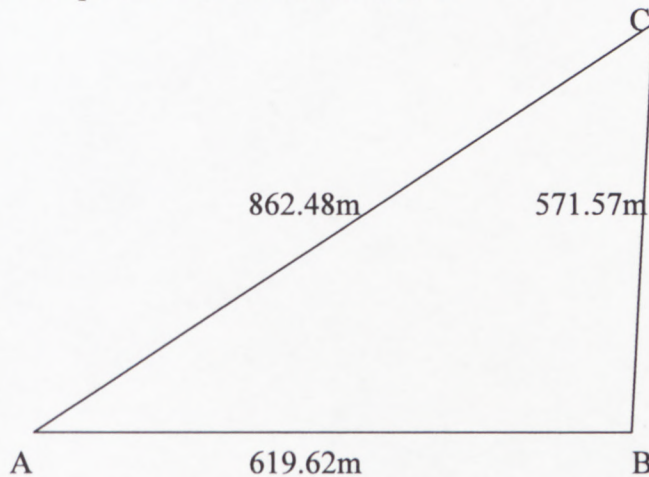
$$f_n = \frac{1}{2\pi} \sqrt{\frac{k \cdot g}{W}}$$

where g is the gravitational constant and k is a constant, W is the Weight. Make W the subject. [4]

SUBTOTAL 8

Question 4

Find the area of a triangular shape of land as indicated below:



[6]

Question 5

a) A shaft is known to have a diameter of 39.000mm. You measure it and get a reading of 37.925mm. What is the percentage error of your reading? [2]

b) An alloy consists of Cu and Zn in the ratio 7.2: 4.3 . Find the percentage composition of the alloy. [3]

SUBTOTAL 5

Question 6

Solve for x:

a) $\log_2 x + \log_2(x - 6) = 4$ [5]

b) $3^{2x} - 78 = 3^{2x-3}$ [5]

SUBTOTAL 10

Question 7

Draw a rough sketch of the following , showing the x and y intercepts

$$y = 6 - x - x^2$$
 [5]

Question 8

The area of a rectangular plot 85mX110m is to be increased by 4100m². If the length and width are increased by the same amount, what are the dimensions of the larger plot? [5]



CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

Foundation Mathematics	
COURSE CODE	
[bc] MAR100	
NQF Level:5 and 6	Credits: 0.0
Faculty: Engineering	Department: Mechanical Engineering
Lecturer: S Mahomed [bc]	Date: Semester 1, 2005
Qualification: National Diploma in Mechanical Engineering -	

PURPOSE

The aim of the course is to enable the student to do basic mathematics, to introduce the student to higher mathematics and mathematical problem solving and to develop a link between mathematics and Mechanical engineering.

Exit Level outcomes:

You will know that you have mastered the outcomes of the course, when:

1. The correct approach to solving a well-defined problem is chosen and justified.
2. The correct mathematical technique is selected for the task.
3. Formulae are correctly selected or constructed from the given unknowns.
4. The answer is correctly calculated and evaluated.
5. The answer makes sense within the context of the problem

LEARNING ASSUMED TO BE IN PLACE:

- a knowledge of matric maths: algebra, trigonometry, analytic geometry and differential calculus.

SPECIFIC OUTCOMES

SPECIFIC OUTCOMES	ASSESSMENT CRITERIA	C C F O , S
1. Do calculator computations and graph sketching.	<ul style="list-style-type: none"> • Use the calculator efficiently. • Sketch graphs: the straight line, parabola, hyperbola, circle, exponential and logarithmic curves. 	1/4/5
2. Define the different forms of a complex number and perform elementary operations on them.	<ul style="list-style-type: none"> • Define the different forms of a complex number: polar, rectangular, exponential and logarithmic. • Convert between the various forms. • Do elementary operations on complex numbers: addition, subtraction, multiplication and division. • Identify a complex number as a vector. 	1/4/5
3. Solve trigonometric equations and identities and analyze the general equation of the sine function.	<ul style="list-style-type: none"> • Solve trigonometric identities and equations. • Analyze the general equation of the sine function: $v = V_m \sin(2\pi ft + \phi) + V_0$ • Define trigonometric/inverse trigonometric functions and sketch their graphs. 	1/4/5
4. Use and apply Euclidean Geometry	<ul style="list-style-type: none"> • know properties of lines, angles , properties of various polygons • geometrical properties related to a circle 	1/4/5
5. Define radian measure and use features of the circle for calculations	<ul style="list-style-type: none"> • Use radian measure. • Calculate lengths of circular arcs and areas of sectors and segments of circles. 	1/4/5
6. Use and apply ratio, proportions and percentages	<ul style="list-style-type: none"> • Know what ratios and proportions are and how to work with them • how to work out percentages and how to apply them 	1/4/5
7. Computing areas within a plane and finding volumes of solid figures	<ul style="list-style-type: none"> • know how to find the perimeter of plane figures • know how to find the area of plane figures • know how to find the volume of solid figures 	1/4/5
8. Do scientific and engineering computations; simplifications and manipulations of formulae	<ul style="list-style-type: none"> • Do computations in decimal, scientific and engineering notation. • Manipulate indices and logarithms, including natural logarithms and change the subject of the formula. 	1/4/5

with indices and logarithms.		
9. Use tables and rules to calculate derivatives of functions.	<ul style="list-style-type: none"> • Use table of standard differential coefficients to calculate derivatives of functions. • Use sum, product, quotient rules to calculate derivatives.. 	1//4/5
10. Apply differentiation in graph sketching, optimization and velocity and acceleration problems	<ul style="list-style-type: none"> • Use the principles of differentiation to aid in graph sketching and maximum/minimum problems. • Use principles of differentiation in solving velocity and acceleration problems. 	1/4/5/ 7
11. Use tables and standard integration techniques to integrate simple functions.	<ul style="list-style-type: none"> • Relate the integral as an anti-derivative. • Use table of standard integration formulae to calculate indefinite integrals of simple functions. 	1/4/5

CRITICAL CROSS-FIELD OUTCOMES (CCFO)

The aim of CCFO's is to direct educational activities towards the development of learners within a social and economic environment. Critical outcomes include, but are not limited to:

1. Identifying and solving problems in which responses display that responsible decisions using critical and creative thinking have been made.
2. Working effectively with others as a member of a team, group, organisation or community.
3. Organising and managing oneself and one's activities responsibly and effectively.
4. Collecting, analysing, organising and critically evaluating information.
5. Communicating effectively using visual, mathematical and / or language skills in the modes of oral and / or written persuasions.
6. Using science and technology effectively and critically, showing responsibility towards the environment and the health of others.
7. Demonstrating an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.
8. Contributing to the full personal development of each learner and the social and economic development of the society at large.

RULES AND RESPONSIBILITIES

Students must familiarize themselves with all rules, policies and responsibilities as outlined in the Program Guide.

RESOURCES

Core notes and tutorials will be made available.

Additional optional support:

[1] Watson et al *Precalculus* Book on short loan [CD's also in the library]

[2] Stroud, K A *Engineering Mathematics* or

[3] Joubert et al, *Technikon Mathematics*

SYLLABUS AND SCHEDULE FOR THE 1ST SEMESTER

Week	Topic
1	<i>The use of the calculator</i>
2	The use of the calculator
3	The straight line and the parabola
4	The straight line and the parabola
5	Linear and quadratic equations
6	Linear and quadratic equations
7	Trigonometry
8	Trigonometry
9	Exponents, radicals, logarithms
10	Exponents and radicals, logarithms
11	Geometry
12	Radian measure
13	Radian measure

Topics for the semester 2

1. Data handling and the use of graphs
2. Complex numbers
3. Ratios and proportion
4. Areas and volumes
5. Graphs, logarithms, tangents, limits, differentiation and integration

ASSESSMENT SCHEDULE:

Course evaluation is continuous, through formative and summative assessments, comprising 3 evaluations per semester made up as follows:

ASSESSMENT	WEIGHTING	DATES	TIME
Midterm assessment	15%	To be announced	2 hours
Class tests,	15%	To be announced	

projects, assignments, tutorials			
Final semester assessment EXAMINER: S MAHOMED, MODERATOR: E CRAWFORD	20%	To be announced	2 hours

BELLVILLE CAMPUS:

LECTURER: S.MAHOMED mahomeds@cput.ac.za ROOM 0105
CONSULTATION: LUNCH TIMES: 13H00– 14H00; MONDAYS AND THURSDAYS

ABSENCE FROM ANY ASSESSMENT WITHOUT A VERY GOOD REASON WILL RESULT IN A “ 0 “ BEING AWARDED. IF SUFFICIENT GROUNDS FOR A SUBSTITUTE ASSESSMENT EXISTS, THE NECESSARY DOCUMENTS (E.G. SICK CERTIFICATE) WILL BE REQUIRED.

NB! ANY QUERY REGARDING A MARK ALLOCATED FOR A TEST, MUST BE RAISED NOT LATER THAN ONE DAY AFTER RECEIVING THE SCRIPT.

Notes

- 1) This document is subject to revision.
- 2) It is the responsibility of the student to ensure that the latest version of this document is used.

END OF DOCUMENT

MAR100 Class test 20.10.05

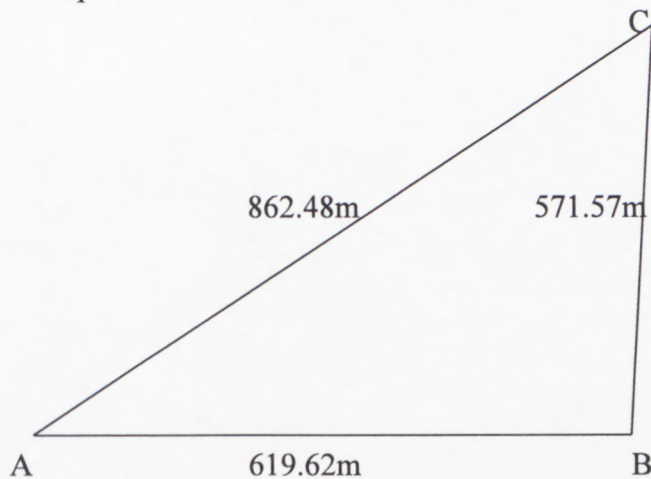
Answer all the questions.

Question 1

A round bar of length 260 mm with diameter 68 mm is melted down and recast into washers 2.8mm thick. Assuming no loss of metal, how many washers can be obtained with internal diameter of 10.8mm and external diameter of 22.6mm. [6]

Question 2

Find the area of a triangular shape of land as indicated below:



[6]

Question 3

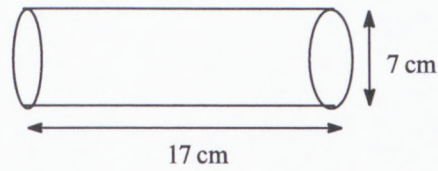
a) A shaft is known to have a diameter of 39.000mm. You measure it and get a reading of 37.925mm. What is the percentage error of your reading? [2]

b) An alloy consists of Cu and Zn in the ratio 7.2: 4.3 . Find the percentage composition of the alloy.[What percentage is Cu and what percentage is Zn?] [3]

Question 4

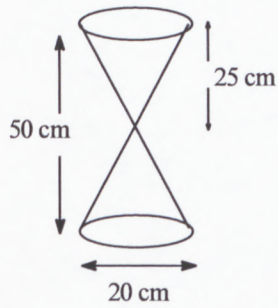
Find the volume of each of the following two figures.

a)



[3]

b)



[5]

<p>A 3D diagram of a cylinder or prism. A horizontal double-headed arrow below the object indicates its height is h.</p>	<p>Any cylinder or prism Right cylinder or prism</p>	<p>Volume = (area of base)(altitude) Lateral area = (perimeter of base) x (altitude) (not incl. bases)</p>
<p>Two 3D diagrams. The top one is a cone with height h and slant height s. The bottom one is a pyramid with height h.</p>	<p>Any cone or pyramid Right circular cone or regular pyramid</p>	<p>Volume = $\frac{h}{3}$ (area of base) Lateral area = $\frac{s}{2}$ (perimeter of base)</p>

MAR100 November Evaluation 2 Nov 2005

Instructions:

4. Answer all questions
5. Start with those you find easier and then return to the rest.
6. smile ☺

100% = 55 Marks

Question 1

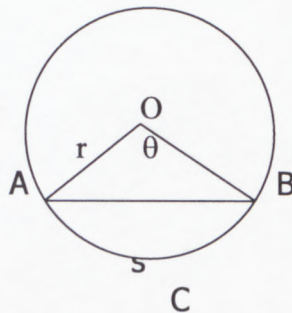
In the figure:

$$0^\circ \leq \theta \leq 360^\circ$$

$$s = \text{arc ACB}$$

$$\text{segment} = \text{ABC}$$

$$\text{sector} = \text{AOBC}$$

1.1 If $r = 1.9\text{m}$ and $\theta = 125^\circ$ calculate the area of AOBC

[4]

1.2 If $r=2.28\text{m}$ and $s = 3.24\text{m}$, calculate the area of ABC

[4]

1.3 If $\theta=74^\circ$ and area ABC = 33cm^2 , calculate r

[4]

1.4 Write the following angles in terms of π : 135° ; 20° ; 160° ; 60°

[2]

SUBTOTAL 14

Useful formulae:

$$\text{Area} = \frac{1}{2} r^2 \theta$$

$$\text{Area} = \frac{1}{2} r^2 (\theta - \sin\theta)$$

$$\theta = s/r$$

[NB: Remember to switch your calculator to radian mode where appropriate]

Question 2

2.1 Use the laws of logarithms to write the following expressions as the sum and difference of logs without using powers. Simplify where possible.

2.1.1 $\log_5\left(\frac{x^2 - y^2}{5}\right)$ [3]

2.1.2 $\ln\left(\frac{\sqrt[3]{y^2 - 4}}{y + 2}\right)$ [3]

2.2 Use the laws of logarithms to write the following expression as a single log

2.2.1 $\log_3 x^3 + \frac{1}{2}\log_3 x^4 - 5\log_3 x$ [3]

SUBTOTAL 9 MARKS

Question 3

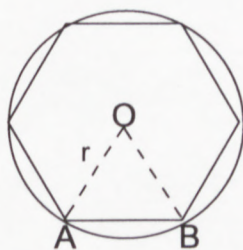
A bolt with a hexagonal head is cut from a bronze rod as shown in the figure below.

3.1) What kind of triangle is ABO? [2]

3.2) What is the size of each angle in the triangle? [1]

3.3) If $r = 35.4$ mm, find the perpendicular length from O to AB. [2]

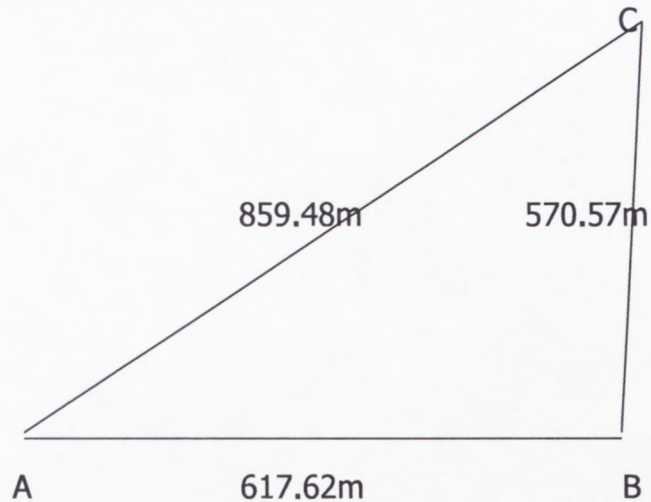
3.4) Find the total area of the pieces that are cut away in making the head of the bolt. [5]



SUBTOTAL 10 MARKS

Question 4

Find the area of a triangular shape of land as indicated below:



[6]

Question 5

a) A shaft is known to have a diameter of 44.000mm. You measure it and get a reading of 42.925mm. What is the percentage error of your reading?

[2]

b) An alloy consists of Mn and Fe in the ratio 9.2: 25.3 . Find the percentage composition of the alloy.

[3]

SUBTOTAL 5

Question 6

Determine θ

6.1 $\sin\theta = 0.734$ $0^\circ \leq \theta \leq 360^\circ$ [2]

6.2 $2 \sec(2\theta + 21^\circ) = 4.3730$ $0^\circ \leq \theta \leq 180^\circ$ [5]

SUBTOTAL 7

Question 7

A farmer's silo is a circular cone 15 m tall. The base radius of the cone is 3 m. Find

- (a) the surface area not including the floor. [3]
 (b) the volume of the cone. [3]



SUBTOTAL 6 MARKS

	<p>Any cylinder or prism Right cylinder or prism</p>	<p>Volume = (area of base)(altitude) Lateral area = (perimeter of base) x (altitude) (not incl. bases)</p>	
	<p>Any cone or pyramid Right circular cone or regular pyramid</p>	<p>Volume = $\frac{h}{3}$ (area of base) Lateral area = $\frac{s}{2}$ (perimeter of base)</p>	

**MATHEMATICS 1 (MARB10) 2002 (Second Semester)
ND. MECHANICAL ENGINEERING**

SYLLABUS:

1. BASIC MATHEMATICS

**1 Radian Measure:
ARCLength; Areas of Circle Sectors and Segments;
Applications**

2.1 ALGEBRA:

2.1.1 REVISION

**MANIPULATION OF FORMULAE; EVALUATION OF UNKNOWNNS
USING
CALCULATOR
INDICES AND LOGARITHMS (USE OF CALCULATOR)**

**2.2 GRAPHS: STRAIGHT LINE, PARABOLA, CIRCLE,
HYPERBOLA,SINE AND COSINE, EXPONENTIAL AND
LOGARITHMIC CURVES**

2.3 TRIGONOMETRY:

2.2.1 REVISION

**DEFINITION: INVERSE FUNCTIONS; IDENTITIES; SOLUTION OF
EQUATIONS**

3 MATRIX THEORY:

3.1 SOLUTIONS OF EQUATIONS USING GAUSS ELIMINATION.

4. DIFFERENTIATION 1

**4.1 BINOMIAL THEOREM; FUNCTIONAL NOTATION; LIMITS; FIRST
PRINCIPALS;**

STANDARD DIFFERENTIAL COEFFICIENTS

4.2 RULES FOR DIFFERENTIATION

**4.3 IMPLICIT DIFFERENTIATION; LOGARITHMIC
DIFFERENTIATION**

**4.4 APPLICATIONS: TURNING POINTS; GRAPH
SKETCHING;VELOCITY AND
ACCELERATION.**

5. INTEGRATION 1

5.1 INTEGRATION SEEN AS AN ANTI-DERIVATIVE

5.2 DEFINITE INTEGRATION

**5.3 INTEGRATION TECHNIQUES: USE OF TABLES AND
SUBSTITUTION**

5.4 APPLICATIONS: AREAS UNDER CURVES AND THE AXIS

DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT: Foundation MATHEMATICS2 [S1 Mathematics]

COURSE: ND.MECHANICAL ENGINEERING

YEAR: 2002

SEMESTER: 1

LECTURER: S Mahomed

MODERATOR: E.G.CRAWFORD

**TEXTBOOK: TECHNIKON MATHEMATICS1 (JOUBERT
ET.AL)**

**ADDITIONAL: MATHEMATICS FOR SCIENTIFIC AND
TECHNICAL**

**STUDENTS. (H.G.DAVIES @ HICKS)
Pre-Calculus 4th Edition [Stewart, Redlin and Watson]
Calculus [International Edition] Gleason A & Hughes-**

Hallett D, et al

EVALUATION METHOD: CONTINUOUS

TEST WEIGHTINGS:	EVALUATION 1:	30% (MID-
TERM TEST)	EVALUATION 2 :	EVALUATION 3
30% (3 SHORT TESTS)		

: **10% (COMB. PROJECT)**
EVALUATION 4 : 30% (FINAL TEST)

RESULT IN A ABSENSE FROM CLASSES WITHOUT REASON, WILL
EVALUATION 2 REDUCTION OF MARKS OBTAINED FOR
TEST WITHOUT A VERY GOOD REASON, ABSENSE FROM A
SUFFICIENT WILL RESULT IN A “ 0 “ BEING AWARDED.IF
),WILL GROUNDS FOR A SUBSTITUTE TEST EXISTS,THE
PLACE ON NECESSARY DOCUMENTS (E.G. SICK CERTIFICATE
BE REQUIRED. THE TEST WILL THEN ONLY TAKE
15/11/2002.

TEST DATES: 4/09/2002 (MID-TERM)
Smaller Class test 18/10/2002 on Differentiation
FINAL TEST DATE : 6/11/2002

NB! ANY QUERY REGARDING A MARK ALLOCATED
FOR A TEST, MUST BE RAISED NOT LATER THAN ONE DAY
AFTER RECEIVING THE SCRIPT.QUERIES FOR REMARK
OF FINAL TEST, MUST BE DIRECTED TO ADMIN.

NB! A FULL OUTCOMES BASED WORK SCHEDULE IS
AVAILABLE ON THE “ STUDENTS NETWORK DIRECTORY”.

CONSULTATION : LUNCH TIMES: 13H00– 14H00 ; TUESDAYS;
THURSDAYS

Appendix I

PROPOSED FOUNDATION STAFFING – DEPT. MECH.ENG.

		Foundation Subjects	Unit Cost		Sem 1 Subjects	Unit Cost
Coordinator Lecturer		Coordination	Foundation Fund R20000			
	½	Foundation Mathematics	Foundation Fund R75000	½	Mathematics I	Dept.Budget R75000
Lecturer	½	Foundation Science	Foundation Fund R75000	½	Mechanics I	Dept.Budget R75000
Lecturer	½	Foundation Language	Foundation Fund R75000	½	Communication I (Support)	Dept.Budget R75000
Lecturer (Dept. contract)	½	Foundation Drawing	Dept. Budget (R75000)			
Admin Support	½	Admin support	R35000	½	Admin support	Dept.Budget

**Peninsula Technikon
National Diploma Mechanical
ENGINEERING MATERIALS AND SCIENCE I - MEM 010
COURSE OUTLINE**

This course is aimed at showing you, the student the importance of materials in engineering. You will also see the inter-related interests of engineers and materials scientists

Specified Outcomes

1. You will be able to describe the properties and behaviour of various materials used in engineering.
2. You will be able to determine these various material properties through mechanical testing.
3. You will be able to explain the changes caused in a material due to the heat treatment of the material.
4. You will be able to explain the change in material structure due to the production and manufacturing processes for the material.

Recommended Reading

Askeland D, The Science and Engineering of Materials – 3rd edition

References

Gordon J E, The New Science of Strong Materials

Alexander W & Street A, Metals in the Service of Man

Hamilton V R, Strength of Materials

Elliot V, Essentials of Strength of Materials

Drotsky J R, Strength of Materials for Technicians

Course Content

1. Five primary groups of materials – Reasons why materials are put into different categories.
2. Basic definitions: Stress, strain, elastic relationships. Why are they

- important and how can we use them to help us.
3. Outlining the most important mechanical tests. (Tensile, torsion, hardness, impact, creep and fatigue)
 4. Detailed descriptions of the most famous of all mechanical tests, the hardness test. Classification of materials based on this test.
 5. Time dependant phenomena: creep and fatigue.
 6. What causes fracture and what can you do to avoid it?
-

7. Working with metals (Heat Treatment)
 - a. Hot working, Annealing and Cold working
 - b. Age and Precipitation Hardening
 - c. Strain Hardening
 - d. Rolling, Drawing and Bending
 - e. Residual Stresses

8. Iron and Steel
 - a. Introduction to steels
 - b. Special steels
 - c. Surface treatments
 - d. Weldability
 - e. Stainless Steels

Evaluations

Course evaluation is continuous, comprising of 6 evaluations made up as follows;

EVALUATION	WEIGHTING	DUE DATE
Assignment 1	30%	15 May 2001
Class Assignments	10%	Ongoing
Laboratories	10%	Ongoing
Test 1	20%	29 March 2001
Final Test (40% sub min)	30%	06 June 2001

Tests and evaluations:

All tests will be carried out in approved venues under strict exam conditions. Students will be informed about venues and starting times well in advance. All projects not handed in on the due date will not be evaluated.

Consultation Times:

Monday 11h05 – 13h00

LECTURER: W KOHLHÖFER, ROOM 0108, MECHANICAL ENGINEERING

Peninsula Technikon

Department of Mechanical Engineering

Engineering Materials and Sciences 1 – MES 010 – Semester 02 – 2003

Homework 01 Given: 31Jul2003 – Due: 07Feb2003

Question 01

Define the following terms:

- 1.) Strength
- 2.) Toughness
- 3.) Fatigue
- 4.) Oxidation
- 5.) Corrosion
- 6.) Abrasion
- 7.) Stress
- 8.) Tension and Compression
- 9.) Protons, Neutrons and Electrons
- 10.) Orbit (chemistry)
- 11.) Fusion
- 12.) Halide
- 13.) Cohesion
- 14.) Bound and Bond (chemistry)
- 15.) Matter

[30]

Question 02

Give a description of the *Periodic Table of Elements*, what it contains, and what it is used for?

[15]

Total: 45marks = 100%

[2004 MES010 Foundation questions]

Question 1

Match the correct number and letter in the table below.

A) Conduction, convection, and radiation, heat exchangers, insulation, and cooling systems.	1) Computer engineering
B) Physical properties of different liquids and gasses and drag, lift and buoyancy forces.	2) Statics
C) Energy conservation and conversion and the efficiency of engines and power generation machinery.	3) Manufacturing science
D) Conceiving a new device and designing it in detail.	4) Machine and product design
E) Experience with computer-aided design, analysis, and manufacturing tools.	5) Heat transfer
F) Machining processes, quality control, and production techniques.	6) Thermodynamics
G) Understanding the forces that act on machines and structures.	7) Fluid mechanics
H) Stresses and deflections of structural components and choosing the materials from which they are made.	8) Dynamics
I) Motion of machine and the forces that are needed to make them move in a desired manner.	9) Solid Mechanics

[9]

Question 2

Is the following statements True or False

1. Primary Bonds are relatively strong bonds and melt between 100 and 500K
2. Secondary Bonds are relatively weak bonds and melt between 1000 and 5000K
3. Ceramics and metals are entirely held together by secondary bonds.

4. Ionic and covalent bonds are strong and stiff bonds and give high moduli.
5. Van der Waals bonding describes the dipolar attraction between uncharged atoms.
6. Amorphous bodies remain solid, i.e. retain their shape, up to a definite temperature at which they change from the solid to liquid state.
7. Crystalline bodies, when heated, are gradually softened in a wide temperature range and become viscous and only then change to the liquid state.
8. The crystalline state of a solid is more stable than amorphous state.
9. If the atoms or ions of a solid are arranged in a pattern that repeats itself in three dimensions, they form a solid, which is said to have a crystal structure and is referred to as a crystalline solid or crystalline material.
10. Most elemental metals (about 90%) crystallize upon solidification into three densely packed crystal structures: Body-centered cubic (BCC), Face-centered cubic (FCC), and Hexagonal close-packed (HCP)
11. The Face-Centered Cubic unit cell has a central atom that is surrounded by 8 neighbours.
12. In HCP crystal structures an atom is surrounded by 12 other atoms.
13. Phase diagrams are graphical representations of what phases are present in a material system at different temperatures, pressures, and compositions.
14. α Ferrite is an interstitial solid solution of carbon in the FCC iron crystal lattice.
15. The solid solubility for carbon in austenite is a maximum of 2,08% at 1148⁰C and decreases to 0,8% at 723⁰C.
16. Cementite (Fe₃C) is a soft and ductile compound.
17. The maximum solid solubility of carbon in δ ferrite is 0,09% at 1465⁰C.
18. At the eutectic reaction point, solid austenite of 0,8% C produces α Ferrite with 0,02% C and Fe₃C which contains 6,67% C.

[18]

Question 3

What is the difference between the following terms?

1. Work and power
2. Potential energy and kinetic energy
3. Process and cycle
4. Friction and Coefficient of Friction
5. Rectilinear motion and angular motion
6. Isothermal process and Isobaric Process
7. Reversible process and Irreversible process
8. Air Conditioning and Refrigeration
9. Gauge Pressure and Absolute Pressure
10. Ductile Material and Brittle Material
11. Elastic Deformation and Plastic Deformation
12. Crystalline and Amorphous Bodies
13. Ferrous and Non-Ferrous Materials
14. Pro-Eutectoid Ferrite and Eutectoid Ferrite
15. Lath and Plate Martensite
16. Stress and Strength

[32]

Question 4

Define the Following terms

1. Temperature
2. Moment of Inertia
3. Work transfer
4. Vector
5. Enthalpy
6. Equilibrium state
7. Combustion
8. Compressible flow
9. Density (σ)

[10]

Question 5

- 1.) State the first two laws of thermodynamics (2)
- 2.) Define Hooke's Law (2)
- 3.) Most elemental metals crystallize upon solidification into three densely packed crystal structures. What are they?

4.) What solid phases are found on the Fe-Fe₃C Phase Diagram? Give a description of each of these phases. (3)

5.) What metallurgical structures are formed when Eutectoid and Hyper-Eutectoid steels are slowly cooled from the austenitic region? (12)

6.) What is the relationship between strength, ductility and carbon content of plain carbon steels. (8)

(4)
[31]

Total = 100Marks = 100%

Memorandum**Question 1**

Match the correct number and letter in the table below.

A) conduction, convection, and radiation, heat exchangers, insulation, and cooling systems.	1) Computer engineering
B) physical properties of different liquids and gasses and drag, lift and buoyancy forces.	2) Statics
C) energy conservation and conversion and the efficiency of engines and power generation machinery.	3) Manufacturing science
D) conceiving a new device and designing it in detail.	4) Machine and product design
E) experience with computer-aided design, analysis, and manufacturing tools.	5) Heat transfer
F) machining processes, quality control, and production techniques.	6) Thermodynamics
G) understanding the forces that act on machines and structures.	7) Fluid mechanics
H) stresses and deflections of structural components and choosing the materials from which they are made.	8) Dynamics
I) motion of machine and the forces that are needed to make them move in a desired manner.	9) Solid Mechanics

[9]

Answer

A – 5

B – 7

C – 6

D – 4

E – 1

F – 3

G – 2

H – 9

I – 8

Question 2**Is the following statements True or False**

19. Primary Bonds are relatively strong bonds and melt between 100 and 500K

[F]

20. Secondary Bonds are relatively weak bonds and melt between 1000 and 5000K [F]
21. Ceramics and metals are entirely held together by secondary bonds. [F]
22. Ionic and covalent bonds are strong and stiff bonds and give high moduli. [T]
23. Van der Waals bonding describes the dipolar attraction between uncharged atoms. [T]
24. Amorphous bodies remain solid, i.e. retain their shape, up to a definite temperature at which they change from the solid to liquid state. [F]
25. Crystalline bodies, when heated, are gradually softened in a wide temperature range and become viscous and only then change to the liquid state. [F]
26. The crystalline state of a solid is more stable than amorphous state. [T]
27. If the atoms or ions of a solid are arranged in a pattern that repeats itself in three dimensions, they form a solid, which is said to have a crystal structure and is referred to as a crystalline solid or crystalline material. [T]
28. Most elemental metals (about 90%) crystallize upon solidification into three densely packed crystal structures: Body-centered cubic (BCC), Face-centered cubic (FCC), and Hexagonal close-packed (HCP) [T]
29. The Face-Centered Cubic unit cell has a central atom that is surrounded by 8 neighbors. [F]
30. In HCP crystal structures an atom is surrounded by 12 other atoms. [T]
31. Phase diagrams are graphical representations of what phases are present in a material system at different temperatures, pressures, and compositions. [T]
32. α Ferrite is an interstitial solid solution of carbon in the FCC iron crystal lattice. [F]
33. The solid solubility for carbon in austenite is a maximum of 2,08% at 1148⁰C and decreases to 0,8% at 723⁰C. [T]
34. Cementite (Fe₃C) is a soft and ductile compound. [F]
35. The maximum solid solubility of carbon in δ ferrite is 0,09% at 1465⁰C. [T]
36. At the eutectic reaction point, solid austenite of 0,8% C produces α Ferrite with 0,02% C and Fe₃C which contains 6,67% C.

Question 3

What is the difference between the following terms?

17. work and power

the product of the average force and the distance moved by its point of application in the direction of the force and the rate of doing work or work per unit of time

18. potential energy and kinetic energy

the energy the body possesses due to its position and the energy the body possesses due to its velocity

19. process and cycle

Any change from one state to another is called a process while A process with identical end states is called a cycle.

20. friction and Coefficient of Friction

a force that resists motion when two surfaces slide over each other and this is a value (usually between 0 and 1) that determines whether or not objects can slide over each other. The bigger the value the more difficult it is for these objects to slide over each other and it depends on the surface of the objects.

21. rectilinear motion and angular motion

motion along a straight line and motion in circle

22. Isothermal process and Isobaric Process

one that occurs at constant temperature and one that occurs at constant pressure

23. Reverseable process and Irreversible process

one that occurs such that the initial state of the system can be restored with no observable effect on the system or the surrounding and one that occurs such that the initial state of the system cannot be restored without observable effect on the system or the surrounding.

24. Air Conditioning and Refrigeration

Air conditioning is the means to control atmospheric environment in private and public buildings for the comfort of human beings or animals or for the proper performance of some scientific or industrial processes. Full air conditioning systems control purity, movement, temperature and relative humidity of the air while refrigeration the withdrawal of heat from a substance or space so that temperature lower than that of the natural surroundings is achieved. Refrigerators use the principle that phase change from liquid to gas involves the absorption of large amounts of heat (energy in motion). In refrigerators this phase change principle is applied to draw heat out of the fridge and transport it to the outside.

25. Gauge Pressure and Absolute Pressure

pressure as measured using an instrument and Gauge Pressure + Atmospheric pressure

26. Ductile Material and Brittle Material

the ability of a material to withstand large deformation under load before fracture occurs. The large deformation is accompanied by visible changes in the materials dimensions and gives warning of impending failure. Materials in this category include mild steel, certain polymers, aluminum, some alloys and copper and the material has a small deformation before fracture occurs. The strain is normally less than 5%. These materials may fail without any visible warning. Included in this group are concrete, cast iron, high-strength steel, timber and ceramics.

27. Elastic Deformation and Plastic Deformation

A material is said to be elastic if deformations disappear completely on removal of an applied load. All known engineering materials are elastic, in addition, linearly elastic within certain limits of stress so that strain, within this limit, is directly proportional to stress and A material is perfectly plastic if know strain disappears after removal of load. Ductile materials are elasto-plastic and behave in an elastic manner until its elastic limit is

reached after which it behaves plastically. When the stress is removed the elastic component of strain is recovered and the plastic strain remains as a permanent set.

28. Crystalline and Amorphous Bodies

Crystalline bodies remain solid, i.e. retain their shape, up to a definite temperature (melting point) at which they change from the solid to liquid state.

Amorphous bodies, when heated, are gradually softened in a wide temperature range and become viscous and only then change to the liquid state.

29. Ferrous and Non-Ferrous Materials

Alloys based on Iron are called FERROUS ALLOYS (iron as the principal alloying metal) and those based on other metals are called NONFERROUS ALLOYS (principal alloying metal other than iron).

30. Pro-Eutectoid Ferrite and Eutectoid Ferrite

Pro-Eutectoid Ferrite is formed before the eutectoid temperature is reached and Eutectoid Ferrite is formed by the eutectoid reaction.

31. Lath and Plate Martensite

If the steel contains less than about 0.6% C, the martensite consists of *domains* of laths of different but limited orientations through a whole domain.

As the carbon content of the Fe-C martensites is increased to above about 0.6% C, a different type of martensite, called *plate martensite*, begins to form.

Above about 1% C, Fe-alloys consist entirely of plate martensite.

32. Stress and Strength

Strength of a material is the stress at which a material will fracture under load, while stress intensity is defined as that force applied to a body divided by the cross-sectional area over which that force is applied.

[32]

Question 4

Define the Following terms

10. Temperature - the degree of hotness of a body, substance, or medium, especially as measured on a scale that has one or more fixed reference points
11. Moment of Inertia - when the mass of every particle of a body is multiplied by the square of the distance from the axis, the summation of these quantities for the whole body is termed the moment of inertia.
12. work transfer - this occurs across a system boundary by virtue of a potential property difference, other than temperature
13. vector - a quantity which possesses both magnitude and direction
14. enthalpy - the heat content or total heat in a thermodynamic process in which the internal energy and pressure-volume properties are combined such that $h = u + Pv$
15. entropy - a thermodynamic quantity that changes by an amount equal to the heat absorbed or emitted divided by the thermodynamic temperature
16. equilibrium state - a system is in equilibrium if its properties do not change in value when the system is isolated from its surroundings
17. Combustion – a chemical reaction which takes place at a high temperature and is accompanied by the release of energy.
18. Compressible flow – a flow that involves the change in the density of the fluid
19. Density (σ) – the mass of a small fluid element divided by its volume

[10]

Question 5

1.) State the first two laws of thermodynamics

Answer

The first law of thermodynamics is simply an expression of the conservation of energy principle, and it asserts that energy is a thermodynamic property.

The second law of thermodynamics asserts that energy has quality as well as quantity, and

actual processes occur in the direction of decreasing quality of energy.

(2)

2.) Define Hooke's Law

Answer

Hooke's Law is an experimental observation that, when strains are small, the strain is very nearly proportional to the applied stress for many materials.

(2)

3.) Most elemental metals crystallize upon solidification into three densely packed crystal structures. What are they?

Body-centered cubic (BCC)

Face-centered cubic (FCC), and

Hexagonal close-packed (HCP)

(3)

4.) What solid phases are found on the Fe-Fe₃C Phase Diagram? Give a description of each of these phases.

Answer

The Fe-Fe₃C contains the following solid phases: **α (alpha) ferrite**, **austenite gamma (γ)**, **cementite (Fe₃C)**, and **δ (delta) ferrite**.

- **α Ferrite:**
 - This phase is an interstitial solid solution of carbon in the **BCC** iron crystal lattice. (Carbon located in)
 - The Fe-Fe₃C phase diagram shows carbon is only slightly soluble (ability to dissolve) in **α Ferrite** reaching maximum solid solubility of 0.02% at 723°C.
 - The solubility of carbon in **α Ferrite** decreases to 0.005% at 0°C.
- **Austenite (γ):**
 - The interstitial solid solution of carbon in **γ iron** is called **austenite**.
 - Austenite has an **FCC** crystal structure and a much higher solid solubility for carbon than α ferrite.
 - The solid solubility for carbon in austenite is a maximum of 2,08% at 1148°C and decreases to 0,8% at 723°C.
- **Cementite (Fe₃C):**
 - The inter-metallic compound **Fe₃C** is called **Cementite**.
 - **Cementite** has negligible solubility limits and a composition of 6,67% C and 93,3% Fe.
 - **Cementite** is a hard and brittle compound.
- **δ Ferrite:**
 - The interstitial solid solution of carbon in **δ iron** is called **δ ferrite**.
 - It has a **BCC** crystal structure.
 - The maximum solid solubility of carbon in **δ ferrite** is 0,09% at 1465°C.

(12)

5.) What metallurgical structures are formed when Eutectoid and Hyper-Eutectoid steels are slowly cooled from the austenitic region?

Answer

Eutectoid

- If a sample of eutectoid steel (plain carbon steel of 0,8%C) is heated to about 750°C and held for a sufficient time, its structure will become homogeneous austenite.
- This process is called **austenizing**.
- If this eutectoid steel is now very slowly cooled to just about the eutectoid temperature its structure will remain austenitic.

- Further cooling to the eutectoid temperature or just below it will cause the entire structure to transform from austenite to a **lamellar structure** (thin membranes) of alternate plates of α Ferrite and Fe_3C .
- This eutectoid structure is called **pearlite**, since it resembles mother-of-pearl.
- Since the solubility of carbon in α Ferrite and Fe_3C changes very little from $723^{\circ}C$ to room temperature, the **pearlite** structure will remain essentially unchanged in this temperature range.

Hyper-Eutectoid

- If a sample of 1,2%C is heated to about $950^{\circ}C$ and held for a sufficient time, its structure will become essentially all austenite.
- If this temperature is now cooled very slowly, **pro-eutectoid cementite** will begin to nucleate and grow primarily at the austenite grain boundaries.
- With further slow cooling to just about $723^{\circ}C$, more **pro-eutectoid cementite** will be formed at the austenite grain boundaries.
- If conditions approaching equilibrium are maintained by slow cooling, the overall carbon content of the austenite remaining in the alloy will change from 1,2% to 0,8%.
- With still further cooling to $723^{\circ}C$ or just below it, the remaining austenite will transform to pearlite by the eutectoid transformation.
- The cementite formed by the eutectoid reaction is termed **eutectoid cementite** to distinguish it from **pro-eutectoid cementite** which forms first above $723^{\circ}C$.
- Similarly the ferrite formed at the eutectoid reaction is termed **eutectoid ferrite**.

(8)

6.) What is the relationship between strength, ductility and carbon content of plain carbon steels.

Answer

- The hardness and strength of Fe-C martensites are directly related to their carbon content and increase as the carbon content is increased.
- However, ductility and toughness also decrease with increasing carbon content, and so most martensitic plain-carbon steels are tempered by reheating at a temperature below the transformation temperature of $723^{\circ}C$.

(4)

[31]

Total = 100Marks = 100%

Peninsula Technikon

**National Diploma Mechanical
ENGINEERING MATERIALS AND SCIENCE I - MES 010
COURSE OUTLINE**

This course is aimed at introducing the student to the world of engineering and what it is that engineers really talk about. The definitions and applications of Mechanical Engineering concepts will form the basis of the study of Mechanical Engineering. All of the concepts will be dealt with at an elementary level so that by the next level the student will recognise and quickly identify with the specialised discussions in courses such as the Strength of Materials, Fluid Dynamics, Applied Thermodynamics, Mechanics and so on. The importance of materials in engineering and how they impact, and are inter-related to the interests of engineers and materials scientists will also be discussed.

Specified Outcomes

5. You will be able to have an understanding of the scientific and technological nature of our immediate surrounding.
6. You will be able to have an understanding of the language and terminology as used on a daily basis by mechanical and other engineers.
7. You will be able to express the mechanical engineering statements into equation and formula form. In other words, instead of writing long-winded sentences, you will be able to use symbols together with the equal sign (=) to make a true mathematical statement.
8. You will be able to describe the properties and behaviour of various materials used in engineering.
9. You will be able to determine these various material properties through mechanical testing, and be able to explain the changes caused in a material due to the heat treatment of the material.
10. You will be able to explain the change in material structure due to the production and manufacturing processes for the material.

Recommended Reading

Askeland D, The Science and Engineering of Materials – 3rd edition

References

Gordon J E, The New Science of Strong Materials

Alexander W & Street A, Metals in the Service of Man

Hamilton V R, Strength of Materials

Hamilton V R, Mechanics of Machines

Elliot V, Essentials of Strength of Materials

Drotsky J R, Strength of Materials for Technicians

COURSE CONTENTS

9. Definitions of major mechanical engineering fields (*Strength of Materials, Fluid Dynamics, Thermodynamics, Mechanics, Mechanics of Machines, Manufacturing and Production Engineering, etc. etc.*) - how mechanical engineering impacts on our lives.
10. Basic definitions of major mechanical engineering terms. What mechanical engineers usually talk about, and what they mean when they say what they say. (*Density, stress, strain, humidity, vapour, liquid, steam, work, specific capacities, air, refrigerants, engineering materials, beams, rate of change, etc. etc. etc.*)
11. Introduction to Engineering Materials (*Classification of Engineering Materials, Definition of Stress, Strain and Elastic Modulus, Bonding of Atoms, Structure of Materials, Principles of Crystallography*)
12. Engineering Alloys, Phase Diagrams, Iron-Iron Carbide Phase Diagram, Slow Cooling of Plain Carbon Steels, Heat Treatment of Plain Carbon Steel
13. Principal Kinds of Heat Treatment of Steel (*Annealing, Normalizing, Hardening, Tempering*)
14. Various primary groups of materials – Reasons why materials are put into different categories. (*Ferrous and Non-Ferrous Materials*)

15. Outlining the most important mechanical tests. (*Tensile, torsion, hardness, impact, creep and fatigue*)
16. Time dependant phenomena: creep and fatigue.
17. What causes fracture and what can you do to avoid it?
18. Iron and Steel (*Introduction to steels, Special steels, Surface treatments, Weldability, Stainless Steels*)
19. Selection of Materials for Design

Evaluations

Course evaluation is continuous; comprising of 5 evaluations as follows:

EVALUATION	WEIGHTING	DUE DATE
Class Assignments	20%	TBA
Laboratories (Tensile Test)	10%	TBA
Mid-Term Test	20%	18/03/2004
Integrated Project	20%	TBA
Final Test (40% sub min)	30%	07/06/2004

Tests and evaluations:

All tests will be carried out in approved venues under strict exam conditions. Students will be informed about venues and starting times well in advance. All projects not handed in on the due date will not be evaluated.

Consultation Times: Wednesday 09h00 – 10h00

LECTURER: O. Philander, ROOM 0115, MECHANICAL ENGINEERING

Email: philandero@pentech.ac.za

MODERATOR: M. Ludick

Appendix O

Company name	Thinking skills needed for success	Classification	Shortcomings of in-service students/employees with a mechanical engineering technical university background	Classification
National A	Comprehension of factual knowledge; justify and interpret, evaluate, with routine procedure the least desired skill, relatively.	Group C Group B Group A	Some specific areas where students struggle include professional communication (written, verbal, presentation skills) as well as quickly developing to a level of independence (unsupervised activity). Students struggle most with evaluation and implications	Group C
International A	The student must have the ability to choose and apply the appropriate techniques using algorithms.	Group B Group C	Choosing the right formulae (first time round) to solve the unknown in various situations is what we have found the students' to be struggling with. Admittedly, there are many variables associated with one object/problem, however, if the student has an adequate	Group B Group C

			knowledge and understanding of mathematics skills, then finding the right formulae or checking the correctness of his/her work should not be a problem.	
Local A	Knowledge of the field; keep up to date; computer skills	Group A	Applying their knowledge; not enough practical experience	Group B
Support for nuclear industry	Interpreting and justifying; report writing; general knowledge of the field	Group C Group A	Making the link between their lectures and practice (interpret); dealing with people; application of knowledge	Group C Group B
Local B	Knowledge and interpretation 50-50	Group A Group C	To find their own solution (interpretation)	Group C
National B	Use initiative; think for themselves;	Group C	Putting theory into practice	Group C Group B
Local C	Interpretation of a few formulae that are often used; power calculations-engineering is about energy transfer; dimensional analysis; ability to see simplicity in various situations	Group C Group B	Too little practical experience	Group C Group B

Shipping A	Depends where student is being used; MD (engineer) does the calculations; need people to execute and then repeat these	Group A	Nothing	n/a
National C	Fault finding	Group C	Not fair to say as skill takes years to develop	n/a
Metal A	Lateral thinking; analytical; problem solving	Group C	Don't have basic knowledge; not know the engineering principles; can draw but cannot 'see' the limits and fits	Group A Group B Group C
Air Conditioning A	Understanding Maths very important; work out formulae; work with motors, pulleys, changing of ratios; need to read and understand drawings; see and think in 3D	Group C Group B	The same areas that are needed	Group C Group B
International B	Global view of how change in one department will impact on others; autocad and solidworks	Group C Group A	They know but cannot convey in words	Group C
Aeronautical A	Lateral thinking; self motivation	Group C	Problem many land up here but had never started out being interested in this field; do not have practical experience but this is	Group C

			not a major problem	
Metal B	Micrometers; CNC lathes; quality assurance; safety and fault finding	Group A Group C	Students are fully equipped but many cannot use basic tools like verniers and micrometers	Group A
Local D	Strength of materials; ability to learn	Group A Group C	Students learn quickly but they cannot interpret drawings	Group C
Local E	Ability to interpret and communicate results; ability to understand and guide artisans; fault finding; understand interconnections between electrical and mechanical	Group C	Although students are humble and prepared to learn, they don't know their basic tools; their interpretation of what you say is very funny sometimes	Group A Group C
Local F	Critical thinking; need to question; be able to go to 1 st principles, ability to analyse and synthesise	Group C	Have interviewed UCT, Stellenbosch, CPUT, have taken no-one; students do not know basic questions; not able to think out of the box	Group C Group A
Air- conditioning B	Drawing production; load calculations; ability to interpret drawings; visualize in 3D; apply thermo and fluids; fault finding; familiarity with basic components; see interconnection	Group A Group B Group C	Although students are willing to learn, they lack practical experience; they cannot visualize in 3D; they cannot see globally how one system fits into another	Group C

	between mech, elec and architecture			
air-conditioning C	Thermo skills – pipes, pumps, hydraulics; grasp the fundamentals of power and energy; enthusiasm; self starters		Interpreting and putting in writing poor; cannot do basic calculations of circumference of circle; autocad	Group C Group A Group B
Local G	Must have ability to design; proficient in autocad; self-active; able to identify problems	Group C Group B	Students lack confidence in applying their knowledge; not self starters; not able to design; lack of English ability, not lack of knowledge; students not in field because of a passion for engineering but perhaps for other reasons	Group C Group B

2003 INTEGRATED PROJECT GUIDELINES

A. Broad Outcomes:

- to integrate subject knowledge
- to apply subject knowledge in order to solve engineering problems
- to experience, manage and take responsibility for a relevant industrial type project
- to evaluate and make decisions

B. Project Outputs:

Outputs expected will vary as the level of complexity will increase across the levels.

- (i) Foundation - research a community need
- (ii) S1 - manufacture and evaluate manufacturing processes of an existing component
- (iii) S2 - feasibility study on existing design
- (iv) S3 - modification to existing design
- (v) S4 - open-ended new design

At S3 and S4 levels the following outputs will be expected:

1. **Design** - concept design, catalogue selections, calculations, safety factors, substantiated decisions, substantiated assumptions
2. **Drawing** - freehand sketching, concept sketching, component detailed drawings, assembly drawings
3. **File of evidence** - this file will include evidence of the design and drawing stages as well as all required mentor visit sheets.
4. **Functional (scale) Model** - this model will demonstrate acceptable design criteria were used
5. **Report** - the report should be based on the file of evidence
6. **Oral Presentation** - based on the report

C. Resources and Support required by students to produce outputs:

Resources required:

- Clear briefs
- Materials
- Funds for buy-out items
- Computers / internet
- Engineering journals / catalogues / easidex / yellow pages
- Alumni lists

- Transport – the possibility to assist students with transport for gathering information will be investigated

Support required:

- More scheduled workshop time
- More scheduled mentoring time
- Lab technicians to manufacture complicated components for students
- Writing centre to assist with report writing

D. **Essential skills required by students to produce outputs:**

- Drawing skills
- Manufacturing skills (basic)
- Information search - sourcing engineering components
 - internet, library, journals, catalogues, easidex, yellow pages, companies
- Report writing skills
- Project management skills
- Group dynamics
- Presentation skills
- Basic problem solving skills
- Feasibility studies (including Excel costing)
- Subject knowledge

E. **Management Process:**

- Mentors allocated to one level only
- Mentoring load to be balanced with level coordinators mentoring just one group
- Group sizes to be between 3-6 with students choosing their own groups
- Groups will be addressed by level coordinators every Wednesday
- In order to stress the importance of the project the coordinators must arrange an address by industry, past students, industry specialists etc. at first meeting
- Coordinators must set the standards for the project by showing a file that scored high marks and/or a well manufactured model of a good design.
- All mentors will require the following items in the group files:
 - i. Groups must have a file with first appointment
 - ii. Project brief, showing mark allocation clearly
 - iii. Project plan
 - iv. Attendance register forms
 - v. Minutes of every meeting, showing deliverables required
 - vi. Assessment form, showing progress marks
 - vii. Submission checklist
 - viii. Relevant documentation as evidence of work produced e.g. concept sketches, calculations, tables, extracts from catalogues, pictures etc.

- Project weighting:

The weightings shown below will be the **MINIMUM** weighting per level. Weighting per subject may vary depending on the significance of the subject to the project at a particular level.

LEVEL	WEIGHTING (min)
Foundation	10%
S1	10%
S2	15%
S3	15%
S4	20%

E. **Marking and Moderation:**

If any of the outputs are not completed on due date, zero will be awarded for that particular output. To continue with the project that particular deliverable has to be submitted first (without marks).

If any of the outputs are not at least attempted, a zero will awarded for the entire project.

The design, drawings, functional model and file of evidence will account for 70% of the marks and the report and oral presentation for 30%.

For consistency all deliverables must be submitted to the level coordinator.

- Files of evidence are marked by the individual mentors and then moderated by all the mentors at that level.
- Functional models are marked by mentors and moderated by all mentors on that level.
- Reports are marked by the individual mentors and then moderated by all the mentors at that level.
- Presentations are marked by level coordinators, together with at least one mentor. Mentors could rotate throughout presentations.
- A presentation at concept phase will be marked by the coordinator and moderated by an industry representative. Marks will count towards the final presentation.
- A self-evaluation checklist will also be made available to students so they can evaluate their own work before handing in.

F. **Feedback:**

- Explicit corrections, suggestions and recommendations by mentors are to be recorded in the minutes during mentor visits.
- Progress marks will be made available on the student shared folder.

ALLOCATION OF PROJECTS

- all full-time students must do a combined project.
- the level of the project will depend on the subjects passed.

PART-TIME STUDENTS

- bona fide (*person who is employed full-time at an outside company*) part-time students, registered for only one subject, may arrange a suitable project from their workplace.
- these projects must have the same outputs and will be evaluated according to the same criteria

PROJECT LEVEL ASSIGNED TO

1. Link subjects: S1 – Manufacturing I MIE010
 S2 – Manufacturing II MIE020
 S3 – Design II MMC020
 S4 – Design III MMC030
2. In the case of a student not registered for any of the above subjects, the student then does the project at the level at which most of the subjects registered

NOTE: In the case of a tie, the lower level takes precedence.

3. Late registration and amendments will not affect the initial project level allocation.

PROJECT WEIGHTING

Each subject will have an evaluation labeled combined project. The final overall mark the obtained for the combined project will then be entered. The **minimum** weighting per level will be as follows:

S1	10
S2	15
S3	15
S4	20

TYPES OF PROJECTS

Broad description of projects

- F1: Identifying need in community and developing a conceptual solution
- S1: Manufacturing of an existing design (manufacturing drawings supplied)
- S2: manufacturing (drawings to be produced) existing product (reproducing), recommend design improvements,
- S3: Improving existing design based on failure analysis
- S4: Own design, analysis of design, aesthetics in design, creativity

Apart from the given projects, students are free to propose their own projects that meet their level requirements.

Needs identified at foundation or other levels should be considered for the following semester's project topics

Projects may be carried through to a following level

PROJECT OUTPUTS

- Prototype/model: At a suitable scale
Materials may be substituted
Could be only of a critical part of the design
- Report: Type written
Formal and Layout dependant on project
- Presentation: Oral presentation using relevant and effective presentation aids
- Project file: Containing all work done on project
Record of mentor visits
Record of mentor comments
- Poster: Minimum size A1 (S3, S4 only)

GROUPWORK

- students will be allocated to groups by the level coordinator. This could be done by student choice or by merit on the first day, thereafter randomly by level coordinators whim)
- it is the student's responsibility to ensure their name is on a list with a project coordinator by the end of registration.
- it is the student's responsibility to produce a workschedule / plan for the project at the start of the project
- groups should consist of a minimum of 3, maximum 5 members
- groups must nominate a spokesperson and the roles of the other members at their first meeting and give the name to the level coordinator
- group allocations will not be changed during the semester
- any delinquent group member must be dealt with by the group at mentor meeting where the mentor acts as arbitrator
- all group members must be present at the presentation (group members absent will receive no marks for the project) Doctor certificates will result in an individual oral. No report, no model or no project file, means no presentation and therefore no mark.
- group members will also be given the opportunity to assess the contribution of their group members (this will be done anonymously)
Rate your mates portion of the total mark. Total mark equals percentage times no of group members left at the end.
- formula: 6 scheduled meetings.

CONTACT TIME

- Re-look meeting time

Facilitate group meetings

MINIMUM STANDARDS

- all outputs (report, file, presentation, model) must be presented to qualify for assessment
- mentor consultation meetings? (idea: changing of time slots? Set dates!!! Meetings in addition to set dates are encouraged but do not contribute to formula)
- What constitutes a meeting? TBD next workshop
No progress on mentor's suggestions means this meeting did not take place even if you are there.
- Progress hand-in's:
 - Planning
 - First Draft

MENTOR MEETING PROCEDURE

- meetings must be scheduled before the time
- the mentor completes meeting record form
- the group must keep minutes of the meeting and keep the minutes in the project file
- groups must arrange and attend a minimum of 6 meetings (Refer to Final Marks Calculation)
-

ASSESSMENT

- Assessment will be done according to criteria, well communicated to the students at time of brief.
- Each level will have different criteria.
- Each project will be assessed by a minimum of 2 lecturers. 10% variance is considered agreement.
- The mentor of the group may not evaluate the group but must be present at the evaluation.
- The project will be evaluated only once at the end.
- Students may be assessed as often as they like (by their tutor) to gauge their performance.
- Students will also be given the opportunity to evaluate their peers.
- Right of appeal.

FINAL MARK CALCULATION

$$\left[\frac{\text{GroupworkMark}}{12\%} + \frac{\text{ProcessMark}}{15\%} + \frac{\text{Presentation}}{25\%} + \frac{\text{ProductMark}}{40\%} \right] = \text{FinalMark}100\%$$

Groupwork:

- Visits – 1 per member per visit
- Team Delegation – Team Leader, member delegation, produce work breakdown – once off 8 marks
- Completion of delegated tasks - 3 per member per visit
- Constructive Engagement - 3 per member per visit

TOTAL

50

Process Mark:

Marks are allocated according to how students respond to lecturers suggestions, instructions, comments and use own initiative. Students must show an improvement in the process to obtain marks, as well as evidence of the following:

- Project Statement, Constraints, criteria ... - 5
- Concept Formation – 10
- Design Process – 30 (5 marks x 6 visits)
- Information Gathering – internet, industrial contact, library ... - 15 (5 marks x 3 visits)
- Material selection - 5
- Mock Presentation (visit 6?) - 5

TOTAL

70

Presentation Mark: *No oral - no mark for **entire** combined project.*

- A group mark is given for the presentation material and integration into the presentation (power-point, any visual material) - 40
- Individual mark is then given for the delivery and response to focus area questions as derived from the report or presentation. (Marks may also be allocated to generic non - technical questions. *These will be decided by the different project levels. The questions should prompt*

and help the students.) Refer to M Cloete model for mark allocation.

- 60

- Poster (prize for best 5 posters per level) - 30

TOTAL

130

Product Mark:

- Product (Report or Report and artifact): - 20 (use existing criteria)
- Functionality of concepts/product – 50
- Application of knowledge learned - 20
- Recommendations – 10
- Where product includes an artifact, half of the **product mark** will be assigned to the artifact.

eg. Final product mark = 60% x 4 group members = 240% . This mark is then divided among the members according to who did what. The students will decide this and motivate with reasons. The lecturer may override this distribution depending on evidence from the file and meeting records.

TOTAL

100

OVERALL TOTAL

350

PROJECT DAY

- groups must present their poster and model
- students need to be on hand to explain their projects

MENTOR CO-ORDINATOR RESPONSIBILITIES

- Plan, chair and minute mentor meetings (min fortnightly)
- Allocate groups
- Deal with problems in conjunction with other mentors
- Manage final marksheets
- Brief whole S-Level group of students
- Ensure consistent evaluation by mentors

MENTOR RESPONSIBILITIES

- Schedule and conduct the minimum of 6 meetings
- Ensure that record of each meeting has been kept. (Mentor to sign each minute)
- Ensure students understand both project brief and policy
- Evaluate the project with at least one peer
- Provide ongoing feedback after each student activity
- Monitor student's project time line

TIME LINE

- Project start – 2 weeks after registration day
- Cut-off date for joining a combined project group is 3 weeks after registration day. A student does not need to be fully registered to join a group but must have done the Departmental registration process.
- Presentation, Artifact and Final Report – 2 weeks before final assessment starts

INTEGRATED PROJECT POLICY

FULL-TIME STUDENTS

- All full-time students must do a combined project.

PART-TIME STUDENTS

- bona fide (*persons who are employed full-time at an outside company*) part-time students, registered for only one subject, may arrange a suitable project from their workplace.
- bona fide (*persons only registered for part-time subjects*) part-time students, registered for one or more subjects, will be given a suitable assignment/project by the lecturer
- a full-time student registered for a part-time subject(s) must be allocated to a full-time group for the project

PROJECT LEVEL ASSIGNED TO

1. Link subjects: S1 – Manufacturing I MIE010
 S2 – Manufacturing II MIE020
 S3 – Design II MMC020
 S4 – Design III MMC030
2. In the case of a student not registered for any of the above subjects, the student then does the project at the level at which most of the subjects are registered

NOTE: In the case of a tie, the lower level takes precedence.

3. Late registration and amendments will not affect the initial project level allocation.

PROJECT WEIGHTING

Each subject will have an evaluation labeled “combined project”. The final overall mark obtained for the combined project will then be entered for each subject at that level. The **minimum** weighting per subject per level will be as follows:

S1	10
S2	15
S3	15
S4	20

TYPES OF PROJECTS

Broad description of projects

FOUND: Identifying need in community and developing a conceptual solution

S1: Manufacturing of an existing design (manufacturing drawings supplied)

S2: Feasibility study of existing product (investigation of: suitability of materials & cost-effectiveness of design)

S3: Improving existing design (model of improved design is manufactured)

S4: Own design, analysis of design, aesthetics in design (model is manufactured)

PROJECT OUTPUTS

- Project file: sketches,
Containing all work done on project e.g. concept drawings, calculations, pictures, tables, etc.
Record of mentor visits (attendance report)
Record/minutes of mentor comments/corrections
Marking sheet showing assessment criteria
Group progress mark form
- Prototype/model: At a suitable scale
Materials may be substituted
Could be only of a critical part of the design
- Report: Type written
Format and Layout dependant on project
- Presentation: Oral presentation using relevant and effective presentation aids

GROUPWORK

- It is the student's responsibility to ensure their name is on a list with a project coordinator by the end of registration.

- Students will be allocated to groups by the level coordinator - this could be done by student choice on the first day, thereafter randomly by level coordinators.
- It is the group's responsibility to **produce a project plan** at the start of the project
- Groups could consist of 3 to 6 members
- Groups must **nominate a captain** and **assign duties to the other members** at their first meeting - the captain's name must be given to the level coordinator
- **Group allocations will not be changed during the semester**
- Any delinquent group member must be dealt with by the group at mentor meeting where the mentor acts as arbitrator
- All group members must be present at the presentation (group members absent will receive no marks for the project – an acceptable excuse will result in an individual oral).
- Group members will also be given the opportunity to rate the contribution of their group members. If a lower rating for the contribution of a group member is confirmed, that member will be awarded a mark accordingly.
- The number of scheduled group meetings is determined by level coordinators

CONTACT TIME

- Scheduled mentor meetings will take place on Wednesdays (11h00 – 12h00) and on Fridays (13h00 – 16h00)
- Meetings outside these time-slots are encouraged but must be arranged by appointment between mentor and groups

MINIMUM STANDARDS

- All outputs must be attempted and submitted to qualify for the overall mark
- If an output is not submitted on due date a zero will be allocated for that output – in order to carry on with the project the outstanding output has to be submitted first (without marks).
- No progress on mentor's suggestions/corrections will result in the mentor canceling that appointment

MENTOR MEETING PROCEDURE

- Level coordinators will address groups every Wednesday
- Meetings must be scheduled before the time
- The mentor completes meeting record form
- The group must keep minutes of the meeting in the project file

ASSESSMENT

- Assessment will be done according to criteria, reflected clearly in the brief.
- Each level will have different criteria.
- Each project will be assessed by a minimum of 2 lecturers - 10% variance is considered agreement.
- All completed outputs must be handed in with level coordinators
- Progress marks for deliverables will be recorded in the project file
- Overall progress marks will be displayed on the Student Shared Folder
- Students will also be given criteria for self-evaluation.
- Right of appeal.

FINAL MARK CALCULATION

- The breakdown of final marks will be determined by the type of project and level of complexity.
- Each project's marks allocation will be displayed in the project brief.
- At S3 and S4 levels the design, drawing and model will constitute 70% of the overall value of the project and the report and presentation 30%.

Process Mark(Project file):

- Marks are allocated according to how students respond to the brief requirements as well as to the mentor's suggestions, instructions, comments and use own initiative. Students must show an improvement in the process to obtain marks.
- Students need to substantiate all assumptions, selections and decisions with concept sketches, calculations, detailed drawings, pictures, catalogue/journal copies etc.

Model Mark:

- The model mark will be determined by whether it display functionality of the concept or a key component of the design.

Report Mark:

- The report mark will be allocated according to criteria set out in the brief.

- The report must be in compliance with the relevant standard Department of Mechanical Engineering text formats, structure and layout – copies of these are available on the Student Shared Folder.

Presentation Mark:

- A group mark is given for the presentation according to set criteria – a copy of these criteria will be found on the Student Shared Folder
- Individual mark is then given for the delivery and response to focus area questions as derived from the report or presentation.

No project file, no model or no report, means no presentation and therefore no mark

LEVEL CO-ORDINATOR RESPONSIBILITIES

- Plan, chair and minute mentor meetings (min fortnightly)
- Allocate groups
- Deal with problems in conjunction with other mentors
- Manage final marksheets
- Brief whole S-Level group of students
- Ensure consistent evaluation by mentors

MENTOR RESPONSIBILITIES

- Schedule and conduct the group meetings
- Ensure that record of each meeting has been kept. (Mentor to sign each minute)
- Ensure students understand both project brief and policy
- Evaluate the project with at least one peer
- Provide ongoing feedback after each student activity
- Monitor student's project time line

TIME LINE

- Project start – 2 weeks after registration day
- Cut-off date for joining a combined project group is 3 weeks after registration day. A student does not need to be fully registered to join a group but must have done the Departmental registration process.
- Final Report, Presentation and Model– 2 weeks before final assessment starts

INTEGRATED PROJECT POLICY

1. DEFINITIONS (in terms of this document):

Full Time Student: A person, registered for a qualification, whose main occupation is that of a student. Students on a reduced load or attending some evening classes (for whatever reason) are still deemed as full-time students

Part-Time Student: A person, registered for a qualification, who is permanently employed by an outside engineering company and spends 8 hours per day at the workplace. Proof of employment can be supplied in the form of a letter of appointment or an employment contract. Occasional, temporary or part-time employment of less than 20 hrs per week does not qualify as permanent employment, irrespective of how long a person has been employed as such.

2. PROJECT PARTICIPATION

- All students, full-time or part-time must do at least one integrated project on each level.
- Full-time students, irrespective of the amount of subjects registered for must do an integrated project for every semester of study.
- Part-time students must do at least one project per level (S1, S2, S3 or S4) of study. The project must be done, the first semester of doing a subject at a new level. ***The mark for that project will then be carried to all subsequent subjects registered at that level.***
- Students attending early evening classes will be deemed as full-time students.

3. EXEMPTION FROM PROJECT PARTICIPATION

There are no exceptions from project participation

4. PASS MARK

- A mark of 50% must be achieved in order for a student to progress the next level project.
- Students achieving less than 50% for a project at any level must repeat the project at that level until 50% is achieved.

5. GROUP ALLOCATIONS

- Students may form their own groups.
- Students who have not joined a group will be assigned to a group.

- Students attending evening classes should form groups with other students also attending evening classes.

ASSIGNMENT OF PROJECT LEVELS

- The project level a student is assigned to will be determined by the pre-requisites:
 - S1 - No pre-requisites
 - S2 - MIJ010 & MMDO10
 - S3 - MSH020 & MKDS10
 - S4 - MSH030 & MMC020
- Late registration or subsequent amendments to registration will not affect the project level allocation.

6. PROJECT WEIGHTING

Each subject will have an evaluation labelled "Integrated Project". The final overall mark obtained for the integrated project will then be entered for each subject registered at that semester (full-time students) of that level (part-time students). The **minimum** weighting per subject per level will be as follows:

S1	10 %
S2	15 %
S3	15 %
S4	20 %

TYPES OF PROJECTS

Broad description of projects

- Identifying a need in the community and developing a conceptual solution
- Manufacturing of an existing design (manufacturing drawings supplied)
- Feasibility study of existing product (investigation of: suitability of materials & cost-effectiveness of design)
- Improving existing design (model of improved design is manufactured)
- Own design, analysis of design, aesthetics in design (model is manufactured)

PROJECT OUTPUTS

- Project file: sketches, drawings, calculations, pictures, tables, etc. Containing all work done on project e.g. concept drawings, calculations, pictures, tables, etc.

Record of mentor visits (attendance report)
Record/minutes of mentor comments/corrections
Marking sheet showing assessment criteria
Group progress mark form

- Prototype/model: At a suitable scale
Materials may be substituted
Could be only of a critical part of the design
- Report: Type written
Format and Layout dependant on project
- Presentation: Oral presentation using relevant and effective presentation aids

GROUPWORK

- It is the student's responsibility to ensure their name is on a list with a project coordinator by the end of registration.
- Students will be allocated to groups by the level coordinator - this could be done by student choice on the first day, thereafter randomly by level coordinators.
- It is the group's responsibility to **produce a project plan** at the start of the project
- Groups could consist of 3 to 6 members
- Groups must **nominate a captain** and **assign duties to the other members** at their first meeting - the captain's name must be given to the level coordinator
- **Group allocations will not be changed during the semester**
- Any delinquent group member must be dealt with by the group at mentor meeting where the mentor acts as arbitrator
- All group members must be present at the presentation (group members absent will receive no marks for the project – an acceptable excuse will result in an individual oral).
- Group members will also be given the opportunity to rate the contribution of their group members. If a lower rating for the contribution of a group member is confirmed, that member will be awarded a mark accordingly.
- The number of scheduled group meetings is determined by level coordinators

CONTACT TIME

- Scheduled mentor meetings will take place on Wednesdays (14h00 – 16h00) and on Fridays (14h30 – 16h00)
- Meetings outside these time-slots are encouraged but must be arranged by appointment between mentor and groups

MINIMUM STANDARDS

- All outputs must be attempted and submitted to qualify for the overall mark
- If an output is not submitted on due date a zero will be allocated for that output – in order to carry on with the project the outstanding output has to be submitted first (without marks).
- No progress on mentor's suggestions/corrections will result in the mentor canceling that appointment

MENTOR MEETING PROCEDURE

- Level coordinators will address groups every Wednesday
- Meetings must be scheduled before the time
- The mentor completes meeting record form
- The group must keep minutes of the meeting in the project file

ASSESSMENT

- Assessment will be done according to criteria, reflected clearly in the brief.
- Each level will have different criteria.
- Each project will be assessed by a minimum of 2 lecturers - 10% variance is considered agreement.
- All completed outputs must be handed in with level coordinators
- Progress marks for deliverables will be recorded in the project file
- Overall progress marks will be displayed on the Student Shared Folder
- Students will also be given criteria for self-evaluation.
- Right of appeal.

FINAL MARK CALCULATION

- The breakdown of final marks will be determined by the type of project and level of complexity.
- Each project's marks allocation will be displayed in the project brief.
- At S3 and S4 levels the design, drawing and model will constitute 70% of the overall value of the project and the report and presentation 30%.

Process Mark(Project file):

- Marks are allocated according to how students respond to the brief requirements as well as to the mentor's suggestions, instructions,

comments and use own initiative. Students must show an improvement in the process to obtain marks.

- Students need to substantiate all assumptions, selections and decisions with concept sketches, calculations, detailed drawings, pictures, catalogue/journal copies etc.

Model Mark:

- The model mark will be determined by whether it display functionality of the concept or a key component of the design.

Report Mark:

- The report mark will be allocated according to criteria set out in the brief.
- The report must be in compliance with the relevant standard Department of Mechanical Engineering text formats, structure and layout – copies of these are available on the Student Shared Folder.

Presentation Mark:

- A group mark is given for the presentation according to set criteria – a copy of these criteria will be found on the Student Shared Folder
- Individual mark is then given for the delivery and response to focus area questions as derived from the report or presentation.

No project file, no model or no report, means no presentation and therefore no mark

LEVEL CO-ORDINATOR RESPONSIBILITES

- Plan, chair and minute mentor meetings (min fortnightly)
- Allocate groups
- Deal with problems in conjunction with other mentors
- Manage final marksheets
- Brief whole S-Level group of students
- Ensure consistent evaluation by mentors

MENTOR RESPONSIBILITES

- Schedule and conduct the group meetings
- Ensure that record of each meeting has been kept. (Mentor to sign each minute)
- Ensure students understand both project brief and policy
- Evaluate the project with at least one peer

- Provide ongoing feedback after each student activity
- Monitor student's project time line

TIME LINE

- Project start – 2 weeks after registration day
- Cut-off date for joining a combined project group is 3 weeks after registration day. A student does not need to be fully registered to join a group but must have done the Departmental registration process.
- Final Report, Presentation and Model– 2 weeks before final assessment starts

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- All full-time students must do a combined project.

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FINAL MARK CALCULATION

- The breakdown of final marks will be determined by the type of project and level of complexity.
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Model Mark:

- The model mark will be determined by whether it display functionality of the concept or a key component of the design.

Report Mark:

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- The report must be in compliance with the relevant standard Department of Mechanical Engineering text formats, structure and layout – copies of these are available on the Student Shared Folder.

Presentation Mark:

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No project file, no model or no report, means no presentation and therefore no mark

LEVEL CO-ORDINATOR RESPONSIBILITIES

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- Final Report, Presentation and Model– 2 weeks before final assessment starts

INTEGRATED PROJECTS

REVIEW

DEPT. MECH. ENGINEERING.

JUNE 2004

·ABSOLUTE CLARITY:

- mentors must know exactly what they want
- students must show clear understanding of what is expected before project is started

·ABSOLUTE CONSISTENCY:

- all mentors must manage projects in same way

·Greater Emphasis on Hard Eng Skills:

- Especially Manufacturing Skills

Review Structure

- 1. Why integrated projects – broad outcomes**
- 2. Expected outputs from projects**
- 3. Resources and support required to produce outputs**
- 4. Essential knowledge and skills required**
- 5. Management of process**
- 6. Assessment**
- 7. Moderation & Feedback**
- 8. Policy**

2004

SUMMARY - INTEGRATED PROJECT CONCERNS

Some staff members in the Department of Mechanical Engineering inadvertently placed incomplete and un-moderated integrated project marks on the student shared folder instead of the staff shared folder. Students saw these marks and interpreted them for what it appeared to be. Students then protested about the integrated project marks and used this platform to raise other concerns relating to the integrated project. An investigation was launched in order to determine the facts.

It was decided to look into issues at each level of the Diploma Course. Student representatives were requested to meet with the Head of Department and the mentors of each level together with some students who were allocated to each project mentor. These students could then raise their concerns directly with the mentors.

Students however preferred not to attend the meetings and instead opted to write down their concerns directed at each level project mentor. Student representatives then presented the meeting with these concerns and issues.

In general it was found that almost all concerns and allegations could be clarified by mentors at these meetings. Whilst there were some unfounded allegations there were also some concerns raised which were noted and those would be used to improve the management of integrated projects in the future. However, most of these issues had no impact on the current marks for the projects. A more detailed discussion of the various concerns at each level can be found in the sheets attached.

It was determined that at the S3 and S4 level poor communication by certain mentors, which could have been misinterpreted by students, caused confusion which lead to students not producing models for their projects. Students were given the benefit of the doubt and mentors agreed that students not be penalised for not submitting the model - in both cases the marks for the model was discarded. At S3 level the mark for the model was equivalent to 15% of the total project mark and for S4

it was 20%. The project was thus marked out of the total minus the mark for the model. Those students who did complete a model were given a bonus mark for their effort.

The pass rates for the project on the different levels were as follows:

Foundation level	=	76%
S1 - level	=	53%
S2 - level	=	53%
S3 - level	=	66%
S4 - level	=	51%

Quite a number of student groups (especially at S1 level) did not submit anything or simply withdrew from the project and subsequently received zero. The pass rates reflected above are thus not a true reflection of how the students performed. All zero marks were then omitted from the calculations and the amended pass rates are reflected below:

Foundation level	=	80%
S1 - level	=	71%
S2 - level	=	56%
S3 - level	=	67%
S4 - level	=	56%

It must be noted that the level of complexity increases as students progress through the various levels.

Attached are histograms which reflect the distribution of marks for each level. Whilst staff members acknowledge that there is always room for improvement in terms of the management of the projects it will be noted that the distribution of marks are not excessively skewed.

Staff members also raised some concerns w.r.t. student shortcomings which they feel, if attended to, could impact positively on the marks obtained for the projects. The list with concerns is attached.

Appendix V

Community Project 2003

It is said that Engineers use the laws and forces of nature to benefit humankind. This project is an ideal opportunity for you, as an engineering student, to make your contribution to use your experience, engineering skills and knowledge acquired to improve, enhance or even uplift a particular community.

Part A

This project requires that you:

- go into an underdeveloped/disadvantaged community and do a needs assessment. This means identifying REAL problems in a community that might not be fortunate enough to enjoy the comfort and convenience of modern technology.
- find out directly from people in the community or by observation, what problems (mechanical engineering related) they are experiencing and make a list of these problems. Do not look for BIG problems. Rather focus on something that YOU will be able to solve. Make sure that you understand what the exact situation is because you will have to explain to us (lecturers and students) what you have discovered.
- Work in pairs
- Write a report in which you briefly describe the engineering problem and how you propose to solve or improve the situation. Solving the problem will require some creativity and should be do-able.

PART B

Assume that as part of your community project you are considering to use mild steel, brass or aluminium. To find out more about the properties of these metals you are required to Tensile test a specimen of each of them in the **Strength of Materials laboratory** and write a report.

Task:

You will be required to work in pairs. Each member of the group will share equally the responsibilities and forward one report with appropriate graphs of the test specimens, all on the same set of axes. Full information of findings should be reflected, namely Stress and Strain values, Force and extension values, etc. Compare and interpret the results. Also, compare the mechanical properties of each specimen

eg malleability, ductility, Tensile strength etc, taking measurements both before and after testing.

Reflect on the graphs and compare:

Young's modulus; Elastic limit; Upper and lower yield points; Ultimate strength and breaking point.

General:

You will be evaluated according to the standard 'Evaluation of Combined Assignment' available on the system. Your report must meet all Department criteria and standards and should be at least one full A4 page in length [besides the cover page]. Tables must be done in excel. Calculations are to be done on A4 writing paper.

Table:

The Table below shows the results of a tensile test of a 12.5 mm diameter Aluminium alloy test bar (Original Cross-sectional area $A_0=122.7\text{mm}^2$). Convert the load vs gauge length data in the table to engineering Stress and Strain and plot a Stress-Strain curve showing Young's Modulus, Yield Strength, Tensile Strength, Fracture, Elastic Straining and Plastic Straining. Show all calculations and complete the table in Excel.

Table

MEASURED		CALCULATED	
LOAD	GAUGE LENGTH	ENG STRESS	ENG STRAIN
KN	Mm	MN.m^{-2}	mm.mm^{-1}
0	50	0	0
5	50.03	40.7	0.0006
10	50.06		
15	50.09		
20	50.12		
25	50.15		
30	50.185		
35.3	52		
35.6 Max	53		
33.8 Fracture	55.3		

Sample calculation:

For the 5kN load:

$$\sigma = \frac{F}{A_0} = \frac{5000N}{\left(\frac{\pi}{4}\right)(12.5mm)^2} = \frac{5000}{122.7} = 40.7N.mm^{-2} = 40.7MN.mm^{-2} \quad [\text{Stress}]$$

$$\varepsilon = \frac{l - l_0}{l_0} = \frac{50.03 - 50.00}{50.00} = 0.0006mm.mm^{-1} \quad [\text{Strain}]$$

DUE DATES

Presentation of problems discovered and identification of community

First draft week of **7th April**

Remember that writing is a process and that writing a draft/s will help you to pick up errors, to improve your writing and help your lecturers to make sure that you are on the 'right track'.

Final draft to be submitted on **14th May**

Oral Presentation in the week of the 19th May **TBA**

PROJECT WEIGHTING

The following table shows how much the project counts for each of the subjects:

SUBJECT	%
Communication Skills	25%
Mathematics MAR100	20%
Science MIJ100	
Computer Skills MCPR10	
MES 010	

Outcomes

You should be able to:

- identify a relevant problem in a community
- find a workable solution to this problem
- clearly communicate your problem and solution both in writing and orally
- Perform a Tensile test and write a report of it.

Examples of what communities have done

- There was a newspaper report about a community living next to a river. There was a problem of drownings as there was no bridge over the river. The community developed their own cable car and with pulleys were able to get people safely across and back.
- People living in flats were worried about their clothes being stolen off the communal washing line so someone developed a clothes line that they could extend from their window outwards and then fold up after use. Yet another clothes line was developed where the clothes could be reeled in or out on a pulley system set up outside a window.

Last year the Foundation students came up with imaginative designs. Some of these will be demonstrated. See if you can come up with even better ideas/designs.

Think about problems facing the community such as candles falling over and causing fires, or difficulty in escaping from a shack or small dwelling in a case of fire. What the problems of storing chemicals such as washing liquid or paraffin while there are babies or children around? You could even go to or telephone Red Cross hospital to find out what are the common There are many problems that exist in any community. It is just that we have not sat down and examined them. Explore, feel free to take on anything. Remember it is often the simplest way out that everyone overlooks that can really make a difference in people's lives. Go for it!

Peninsula Technikon
Department of Mechanical Engineering

Departmental Moderators Report

Subject	Examiner	Internal Moderator	External moderator
FOUNDATION INTEGRATED PROJECT	S Mahomed O Philander F Harris R Jhumka A Elms	S Mahomed O Philander F Harris R Jhumka A Elms	

Evaluation date	Evaluation weighting		Test 1	Test 2	Final Test
June 2003					

Examiner Remarks

The community project, lab report and presentation were done to prepare the foundation students for an S1 combined project. The project was evaluated using an S1 standard.

Date: June 2003

Signed:

Internal Moderator Remarks

The effect of such a project had a huge negative impact on all subjects. The project had very little maths and science and fell short of the true integrated project. The assessment criteria used exceeded the requirements for students at the foundation level.

All moderators agreed to raise the combined project marks by 20% across the board. In future we recommend that an appropriate set of assessment criteria be developed for the foundation integrated project.

Date: June 2003

Signed:

Foundation Integrated Project 2004

Part 1 [Semester 1]

It is said that Engineers use the laws and forces of nature to benefit humankind. This project is an ideal opportunity for you, as an engineering student, to make your contribution to use your experience, engineering skills and knowledge acquired to improve, enhance or even uplift a particular community.

This project requires that you:

- go into an underdeveloped/disadvantaged community and do a needs assessment. This means identifying REAL problems in a community that might not be fortunate enough to enjoy the comfort and convenience of modern technology.
- find out directly from people in the community or by observation, what problems (mechanical engineering related) they are experiencing and make a list of these problems. Do not look for BIG problems. Rather focus on something that YOU will be able to solve. Make sure that you understand what the exact situation is because you will have to explain to us (lecturers and students) what you have discovered.
- Work in pairs
- Write a report in which you briefly describe the engineering problem and how you propose to solve or improve the situation. Solving the problem will require some creativity and should be do-able.

DUE DATES

Presentation of problems discovered and identification of community

Finalise concepts Friday 6th February, 1pm
 [Each group must hand in a handwritten page on their concept before 1pm]
 First draft 19th March

Remember that writing is a process and that writing a draft/s will help you to pick up errors, to improve your writing and help your lecturers to make sure that you are on the 'right track'.

Final draft TBA

PRESENTATION [must be at least in MSWord] TBA

PROJECT WEIGHTING

The following table shows how much the project counts for each of the subjects:

SUBJECT	%
Foundation Communication	25%
Foundation Mathematics	15%
Materials and Engineering Science	20%
Foundation Science	25%
Foundation Drawing	25%

Computer Skills [Second semester only]	TBA
Manufacturing [Second semester only]	TBA

For Foundation subjects, your project mark will be half of the above percentage for each semester. Eg, Your project mark for Foundation Mathematics will be 7,5% for each semester.

MARK ALLOCATION:

Overall project mark will be made up as follows:

First Draft	30%
Final Report	45%
Presentation	25%
TOTAL	100%

MAR100 requirements

You will be required to calculate the total volume of the product , and hence the mass. An additional assignment will be given as soon as the list of products have been finalized.

MKD100 requirements

You need to present a typed report [MSWORD] meeting department standards.

MIJ100 requirements

As soon as the project list has been finalized, each group will be allocated a problem to investigate.

MMD100 requirements

On A3 size drawing sheet, make a neat proportional sketch of your design.[1st semester]

MES010 requirements

You need to select 3 possible materials and based on the engineering properties, compare them and decide which material comes closest to what the product requires.

POLICY

The MechEng Department policy on the integrated project applies. Please study this document.

Outcomes

You should be able to:

- identify a relevant problem in a community
- find a workable solution to this problem
- clearly communicate your problem and solution both in writing and orally

Examples of what communities have done

- There was a newspaper report about a community living next to a river. There was a problem of drownings as there was no bridge over the river. The community developed their own cable car and with pulleys were able to get people safely across and back.
- People living in flats were worried about their clothes being stolen off the communal washing line so someone developed a clothes line that they could extend from their window outwards and then fold up after use. Yet another clothes line was developed where the clothes could be reeled in or out on a pulley system set up outside a window.

Think about problems facing the community such as candles falling over and causing fires, or difficulty in escaping from a shack or small dwelling in a case of fire. What the problems of storing chemicals such as washing liquid or paraffin while there are babies or children around? You could even go to or telephone Red Cross hospital to find out what are the common There are many problems that exist in any community. It is just that we have not sat down and examined them. Explore, feel free to take on anything. Remember it is often the simplest way out that everyone overlooks that can really make a difference in people's lives. Go for it!

Part 2 [Semester 2]

By the start of the second semester, you will receive a detailed breakdown of what is required from you as well as the new deadlines. In short, you will be required:

- to build a small scale model of the product that you have researched in the first semester,
- you will have the opportunity to refine your design
- you need to write another final report, including the changes that you have made. Once again a draft of this report will have to be handed in.
- your final presentation must be done in powerpoint.

Foundation Project Initial list 2004

1. *Paraffin lamp upgrade*
2. *Removable burglar bars*
3. Hi tech oxwagon
4. Drainage for wash water
5. *Dog food dispenser*
6. car upgrades [aerodynamic shape, pedestrian friendly lights ; tyre pressure; gas emmissions]
7. New wheel clamp [clamping all 4 wheels and attached to the car]
8. New padlock
9. *Flippable car speakers*
10. cupboard with 'balls'
11. *Moveable gazebo chair for clinic queues*
12. Ashtray with storage space
13. Armchair with accessories [ashtray; glass holder; etc]
14. *Theftproof letter box*
15. waterpump powered by generator
16. Windmill driven water pump
- 17 Table with wheels [with storage space]

The ones highlighted in red are suggested by Margot. We have to finalise the list and allocate these to students. I suggest we give each group that came up with the idea priority to be allocated to that specific group, with the rest having to fill in their names, eg 4 groups could select one project [assuming 6 projects] , with the limitation that 2 of the projects would only have 3 groups each - this adds up to 22 groups [allowing for the fact that the Foundation class will be expanded to 45 students]

PLEASE REPLY ASAP

THANK
SHAHEED

Foundation Integrated Project 2005

Part 1 [Semester 1]

It is said that Engineers use the laws and forces of nature to benefit humankind. This project is an ideal opportunity for you, as an engineering student, to make your contribution to use your experience, engineering skills and knowledge acquired to improve, enhance or even uplift a particular community.

This project requires that you:

- go into an underdeveloped/disadvantaged community and do a needs assessment. This means identifying REAL problems in a community that might not be fortunate enough to enjoy the comfort and convenience of modern technology.
- find out directly from people in the community or by observation, what problems (mechanical engineering related) they are experiencing and make a list of these problems. Do not look for BIG problems. Rather focus on something that YOU will be able to solve. Make sure that you understand what the exact situation is because you will have to explain to us (lecturers and students) what you have discovered.
- You are required to select a project from the following list:
 - a) Improvement to the paraffin stove to eliminate the possibility of fires from it
 - b) Heating of water in an environmentally friendly way
 - c) Using solar energy to power a radio or television [must be a new idea]
 - d) A fire alarm adapted for shacks – a key focus will be adapting what triggers it
 - e) Another project may be chosen only if approved by your mentor
- Work in groups of 3
- Write a report in which you briefly describe the engineering problem and how you propose to solve or improve the situation. Solving the problem will require some creativity and should be do-able. You should present your report to your peers for a public defence.

DUE DATES

First draft

6th April

Remember that writing is a process and that writing a draft/s will help you to pick up errors, to improve your writing and help your lecturers to make sure that you are on the 'right track'.

PRESENTATION [must be at least in MSWord]

11th May

NOTE: a copy of the pre-final draft must be handed in on the

10th May

FINAL DRAFT

16th May

PROJECT WEIGHTING

The following table shows how much the project counts for each of the subjects:

SUBJECT	%
Foundation Mathematics	15% 7,5X2
Foundation Science	15% 7,5 X2
Foundation Drawing	15% 5+ 10
Computer Skills [First semester only]	TBA
Manufacturing [Second semester only]	TBA

For Foundation subjects, your project mark will be half of the above percentage for each semester. Eg, Your project mark for Foundation Mathematics will be 7,5% for each semester.

MARK ALLOCATION:

Overall project mark will be made up as follows:

First Draft	30%
Final Report	45%
Presentation	25%
TOTAL	100%

Presentations are compulsory: NO PRESENTATION – NO MARK
MAR100 requirements

You will be required to calculate the total volume of the product , and hence the mass. An additional assignment will be given as soon as the list of products have been finalized. This depends on the project.

MKD100 requirements

You need to present a typed report [MSWORD] meeting department standards.

MIJ100 requirements

As soon as the project list has been finalized, each group will be allocated a problem to investigate.

MMD100 requirements

On A4 size drawing sheet, make a neat proportional sketch of your design.[1st semester]

MCPR10 requirements

As soon as the project list has been finalized, each group will be allocated a problem to investigate.

General Requirements

You need to select 3 possible materials and based on the engineering properties, compare them and decide which material comes closest to what the product requires.

POLICY

The MechEng Department policy on the integrated project applies. Please study this document.

Outcomes

You should be able to:

- identify a relevant problem in a community
- find a workable solution to this problem
- collect, analyse, organize and critically evaluate information relating to an engineering solution to the problem you have identified

- clearly communicate your problem and solution both in writing and orally
- work effectively in a group to achieve your objectives

The above are in line with all the CCFO's [Critical Cross-field Outcomes].

Examples of what communities have done:

- There was a newspaper report about a community living next to a river. There was a problem of drownings as there was no bridge over the river. The community developed their own cable car and with pulleys were able to get people safely across and back.
- People living in flats were worried about their clothes being stolen off the communal washing line so someone developed a clothes line that they could extend from their window outwards and then fold up after use. Yet another clothes line was developed where the clothes could be reeled in or out on a pulley system set up outside a window.

Think about problems facing the community such as candles falling over and causing fires, or difficulty in escaping from a shack or small dwelling in a case of fire. What the problems of storing chemicals such as washing liquid or paraffin while there are babies or children around? You could even go to or telephone Red Cross hospital to find out what are the common There are many problems that exist in any community. It is just that we have not sat down and examined them. Explore, feel free to take on anything. Remember it is often the simplest way out that everyone overlooks that can really make a difference in people's lives. Go for it!

Part 2 [Semester 2]

By the start of the second semester, you will receive a detailed breakdown of what is required from you as well as the new deadlines. In short, you will be required:

- to build a small scale model of the product that you have researched in the first semester,
- you will have the opportunity to refine your design. You need to test and retest your design to see if it meets the requirements of the problem you identified.
- you need to write another final report, including the changes that you have made. Once again a draft of this report will have to be handed in.
- your final presentation must be done in powerpoint.

CPUT
DEPARTMENT OF MECHANICAL ENGINEERING
FOUNDATION INTEGRATED PROJECT BRIEF 2004

- Title:** Researching a community need and producing a small-scale model
- Project Summary:** In the first semester the Foundation students conducted research on a community need. A list of possible designs were selected for investigation. You now have the choice of further investigating and refining from among the following 3 products: a letterbox ; removable burglar bars ; and a design to improve the safety of a paraffin lamp.
- Broad Outcomes:** to integrate subject knowledge
 To apply subject knowledge in order to solve engineering problems
 To experience, manage and take responsibility for a relevant industrial-type project
 To be exposed to group dynamics
 To evaluate information and make decisions
- Project Outputs:** Typewritten Report
 Small-scale model
 Delivered Oral Presentation
 Project File

Scenario:

You are an engineer based in the Mechanical Engineering Social Responsibility wing. Research has been conducted into specific needs in the community. Three possible designs have been selected. [removable burglar bar; upgrading the safety features of a paraffin lamp; and designing a suitable letterbox]. Choose **one** of the three for you investigation.

You and your team of engineers are required to make improvements on the existing design; conduct market research ; investigate at least 3 different materials then select one of them ; prepare sketches of your new design; build a small scale model of your product ; make recommendations about further design improvements

Evaluation Criteria:

- 1) Planning of activities to produce outputs
- 2) Problem solving approach
- 3) Gathering and analysis of information
- 4) Use of engineering knowledge and skills
- 5) Communication (written and oral)
- 6) Model functionality

See the “Evaluation Criteria” and “Marking Grid” documents for more details. (Note that the project will be evaluated as a whole, separate from individual subjects.)

DATES (to help your planning)

Project Stages	What To Do	Suggested Completion Date	
Analysis and Planning	Project Planning stage, Tasks List, Delegation, Timeframes, Report Outline, Literature Survey, Project File, Scaled drawing of product, list of materials	10%	TBA by moderator
Draft Report submission	There will be ten project review consultations running up to this submission date, appointments to be made with group mentors. ALL MEMBERS OF GROUP TO ATTEND. Each visitation will require proof of new work as well as that of previous meetings. etc. Complete Typewritten and Project File	0%	
Final Report	Complete Typewritten	30%	13 / 10 / 2004 @ 08:25
Presentations	EVERY MEMBER WILL PRESENT. The presentations will be in "MS PowerPoint" Small-scale Product Prototype	30% 30%	21 and 22/ 10 / 2004

GENERAL INSTRUCTIONS

- Students will work in groups as assigned and will report to respective mentors. The mentors will give you tasks aimed at helping you make progress with the project. The outputs from these tasks will need to be hand written on paper as it will be checked and marked.
- Every student must participate and complete an integrated project assignment whether at Foundation, S1, S2, S3 or S4 during the course of this semester. **If not, a zero will be allocated.***
- The manufacturing of the project must include at least FIVE of the following work processes: -
Turning, Milling, Metal removal, Drilling, Joining, Forming, Marking out, Cutting, and Assembly.
- Make a neat-labelled freehand sketch of your project and state the processes you will make use of.
Submit the sketch to your mentor. Your group needs to get approval first before continuing.
- Produce a scaled, detailed, manufacturing drawing of the project.
- Produce a bill of materials and submit to Mr Alexander only.

Use the example below for your bill of materials

Quantity	Length	Material	Metal
1	750x400 mm	1.6 mm sheet metal	Mildsteel
4	450 mm	20 mm square tubing	Mildsteel

- Get approval for your bill of materials and submit to the workshop storeman.
- Your model will be marked according to the following criteria: -

% Complete (have all the processes been performed?)
30%

Functional (can it be used?)

20%

Quality of manufacture (will you buy the product?)

30%

Assembly (is it presentable?)

20%

9. The group must acquire a file (An A4 ring-binding file will do) in which **ALL** project work must be kept, including rough work. These files are what will be evaluated at every stage of the project. The file must contain the project brief, the evaluation criteria and the record of mentor visits and be brought to every mentor visit.
10. To start off you are expected to do some brainstorming and rough planning, and then put together a detailed plan of the entire project, including the manufacturing, the report writing and all the calculations. You also need to conduct market research for similar products.
11. The project will be evaluated as a whole, separate from individual subjects. Compulsory weekly report back and working meetings will be held Wednesdays at 11h15 and Fridays at 1225pm [or at times mutually agreed with your mentor]. Attendance registers will be kept at these meetings and your percentage attendance could be multiplied by your mark if attendance becomes an issue. The project mark will then be used as an evaluation mark in each and every subject you do.
12. Raise group issues/problems with mentors in these meetings as soon as possible. Do not leave group issues to the last minute. **Any group member who does not contribute will be given zero.**
13. The report must show a good command of computer skills, with the various programs MS Word, MS Equation Editor and MS Excel. Use an Excel spreadsheet when giving a table of results.
14. Various subject lecturers will inform you of additional problems that are required for this project. You are required to calculate the volume and mass of the material used for your full-scale product.
15. Final reports are to be submitted no later than 08h25 on the due date, which will be on a Wednesday. On the due date mentors are not available to discuss any aspect of the project and most especially not any printing problems. Printing must be done **before** the due date.
16. The typing format of the project report must conform to the "Assignment Typing Guide Lines" as learned in S1 computer skills and as found on the student shared directory on the PenTech network.
17. Remember that to get any project marks at all, you need to attend the oral presentation and be ready to participate. (Refer to point 12. above on the importance of the project mark.)

NO ORAL - NO MARK ; NO MODEL NO MARK; NO REPORT NO MARK

REPORT LAYOUT AND DISCUSSION OF EACH PARAGRAPH

1. INTRODUCTION

This paragraph must start off by using the facts given in the scenario paragraph above. It may **NOT** contain any references to “students”, “learning”, “school” or “lecturers”.

2. PRODUCT DESCRIPTION

What is the product used for, what does it do and what are its benefits to the person who is buying it? This paragraph would be a good place to include the 3D assembly drawing we did in CAD010.

3. PRODUCT SPECIFICATIONS

Here we will only consider the functions of our product. Each function will have a measurable value. We will quote the range in which our product meets these functions. With specifications we are talking about facts we need to know when buying a product. Specifications are **NOT** a table containing all the sizes of the different parts of our product.

4. MANUFACTURING PROCESS

A good way to start is to give a list of all the parts of the product and then in sub-paragraphs to discuss each one, starting with a separate drawing of the particular part under discussion. “If I read this paragraph I should be able to make the product with no extra help”. Use a **flow diagram** to plan the manufacturing process. Remember that assembly and finishing is also part of the process!

5. PRODUCTION COST

Firstly the production cost per product must be given broken down into material cost, labour cost and machining cost. Next the profit / loss per item must be determined and discussed. **Note** that the source of any cost item given must be included or else it will be considered an inaccurate amount sucked out of your thumb.

6. CONCLUSIONS

This paragraph must start off by saying whether this project is feasible, **yes** or **no**. This answer must be backed by some arguments relating to the financial calculations done in the paragraph on costs. Other conclusions can then be given.

7. RECOMMENDATIONS

Suggest how manufacturing costs can be reduced to make the project more viable or more profitable. This paragraph should include recommendations based on relevant optimization calculations done. (Consult your coursework). **Any suggestions must be motivated.**

8. BIBLIOGRAPHY

List of resources (books, catalogues, interviews, etc) used. List of persons, not at PenTech, consulted (with contact details). List of Internet resources used (if any, as this is not a requirement).

APPENDICES

Any information included in the body of the report that needs to be substantiated especially by calculations must be included in a separate appendix, e.g. optimization calculations, cost calculations, and strength of material calculations. Each appendix must be numbered and have a title. There is no limit on how many appendices you may include. All appendices **must** be referenced from the main body of the report.

Evaluation of the Integrated Assignment

Criteria (Read in conjunction with Criteria for Integrated Assignment)	Poor	Below Average	Threshold Average	Good	Excellent
PLANNING STAGE					
1. Planning of activities to produce outputs					
Planning of information gathering	0	1	2	3	4
Organization of information	0	1	2	3	4
Use Planning Tools (Gantt Chart, Crit Path, etc)	0	1	2	3	4
2. Problem solving approach					
Problem identification, clarification and breakdown (What needs doing)	0	2	4	6	8
Actions to achieve solution identified (Task List)	0	1	2	3	4
Delegation of Tasks (Who's going to do what?)	0	1	2	3	4
Use of Problem Solving Tools (brain-storming, etc)	0	2	4	6	8
Use of Pre-Writing Methods (Report outline, treeing, etc)	0	2	4	6	8
OVERALL PORTFOLIO					
1. Gathering and analysis of information					
Range of sources	0	1	2	3	4
Organization of information	0	1	2	3	4
Evaluation of gathered information	0	1	2	3	4
Originality, Independence, self guidance	0	2	4	6	8
2. Problem solving approach					
Concept formation and material selection	0	2	4	6	8
Degree to which problem is solved	0	2	4	6	8
3. Use of Engineering Knowledge and Skills to solve problem					
Identifying of relevant knowledge required to solve problem	0	2	4	6	8
Application of Engineering Knowledge	0	2	4	6	8
Correctness of Engineering Statements	0	2	4	6	8
Integration of Engineering Knowledge	0	2	4	6	8
Manufacturing Drawings Quality and Standard	0	4	8	12	16
4. Model (Prototype)					
% Complete (All processes performed?)	0	2	4	6	8
Functionality	0	2	4	4	8
Manufacturing Quality	0	2	4	6	8
Aesthetics	0	2	4	6	8
Ease of Assembly	0	2	4	6	8
5. Communication (Written)					
Order and Completeness of Discussion	0	1	2	3	4
Layout and Typesetting	0	1	2	3	4
Overall Impression	0	2	4	6	8
Use of diagrams, tables, sketches, drawings, etc	0	1	2	3	4
Language Use	0	1	2	3	4

Comments	Total	/
	%	
Evaluated By:	Date:	

Foundation Practical 1 [2005]

Aim: Experimental proof of the laws of equilibrium of Forces

Procedure:

Prove that for equilibrium of forces, the algebraic sum of the components of the forces in a given direction is zero. [This is the first condition of equilibrium]

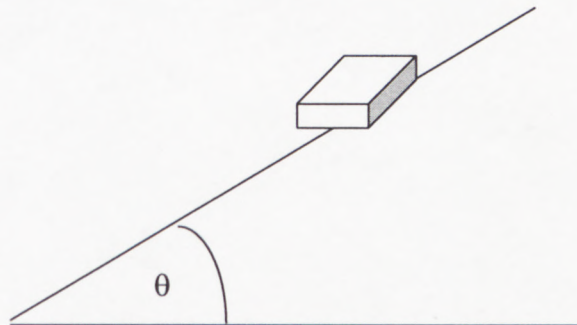
1. Record the masses of the weights marked E , Q, U, and I and calculate their corresponding weights [using $g = 9.81 \text{ m/s}^2$]
2. Stick the paper onto the board, ensuring that the line representing the forces can be marked on the paper.
3. Mark 2 points as far apart as possible in the direction of each of the forces. Ensure that you avoid errors of parallax.
4. Remove the paper from the board.
5. Draw a convenient X-axis on the paper.
6. Extend each of the force lines until they intersect the x-axis that you have drawn.
7. Find the x and y components of each of the forces and find the sum.
8. Compare your expected result from your actual result.

Foundation Practical 2 [2005]

Aim: To establish the coefficient of static friction μ_s for various surfaces.

Procedure:

$$\tan \theta = \mu_s$$



Find the static friction coefficients between various substances and wood. The substances we will investigate are an eraser, a plastic ballpen, a wooden pencil, a R2 coin.

1. Investigate one object at a time.
2. Raise the friction board to the point where each object just about starts to slide.
3. Measure the angle of elevation and calculate μ_s .
4. Take 4 measurements and find the average in each case.
5. Compare the results to the friction co-efficients on page 182 of the Mechanics text.

Foundation Practical 3 [2005]

Aim: To investigate a simple lifting machine.

Procedure:

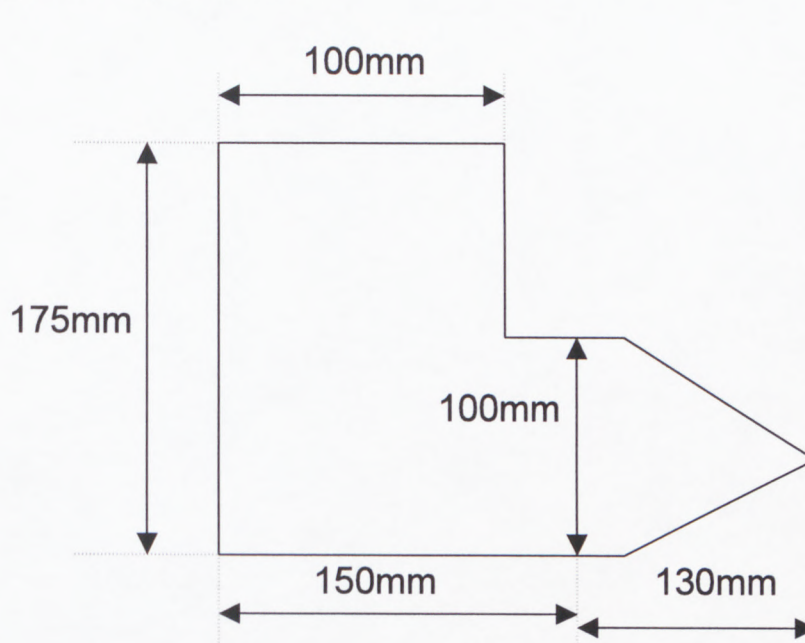
To calculate the Velocity ratio of a stick of Pritt.

1. Measure the diameter of the base of the stick of Pritt gluestick, using the Vernier calipers
2. Remove the cap of the glue stick and measure the length of the glue stick, making sure that the glue is level with the top edge of the stick.
3. Rotate the base through exactly 3 revolutions
4. Measure the length from base to the top edge of the glue, that is standing up out of the stick.
5. Repeat this thrice.
6. Calculate the velocity ratio of the Pritt stick.

[Note: distance moved by the effort = π x diameter of base x number of revolutions]

CENTRES OF GRAVITY PRACTICAL

1. Measure, draw and cut out the following shape on a piece of thin cardboard. This is your lamina.



- Determine the centre of gravity of your lamina by the hanging method.
- Verify your answer with calculations. (make sure that you have a reference point)

HAND IN:

- your measured and cut lamina
- a brief description of your experimental work
- your calculated answer with your calculations as well as an explanation (if necessary) of why there is a discrepancy between your experimental values and your calculated values.

MATERIAL DEVELOPMENT : FOUNDATION LANGUAGE

The existing Foundation Language book is based on the subject Materials Engineering and Science. This subject, which was previously a compulsory subject for S1's, has now become an elective later in the course.

Although quite a bit of what is covered in Materials Engineering and Science is relevant to whatever they do in engineering, some topics covered in the Foundation Language textbook are too detailed and cannot be dealt with in the Foundation Language class only.

My plan for the new textbook is as follows :

- Retain some of the current material in the textbook (properties of materials, material testing & selection of material)
- Include some material that looks at Science (MIJ100) concepts.
- Include some material that looks at Drawing (MMD100) concepts.
- Including text that support a mathematics glossary of terms and concepts.
- Doing Research (different sources of material, planning your research, etc.)
- Dealing with Projects (planning, group work)
- Presentations
- Graphic Literacy

Each of the above topics will be divided into units. Although each unit will cover a certain subject area, the main focus of the book will be to look at language concepts and this will be brought through in the different units.

Language areas that will be focused on in the book :

- Parts of speech (sentence structure)
- Paragraph structure
- Essay structure
- Tenses
- Answering a comprehension
- Summarising
- Vocabulary (prefixes, suffixes, synonyms, antonyms, etc.)

Timeframe for reworking of textbook

Some of the planning for the book has already started.

Most of the writing will take place towards the end of the year with all writing finished by Aug 2006.

The new material will then be trialed on the 2006 Foundation students and the book can be published for 2007.

Felicity Harris
22 September 2005

Outline for reworking of Foundation Mathematics book

Based on a policy decision to shift towards problem /theme based learning and teaching, the existing book will have a substantial addition based on experiments and practicals that will be written.

In addition there are new chapters that need to be added:

New Chapters:

1. Radian measure with practical
2. Complex numbers [after the chapter on Trigonometry]
3. Introduction to costing and budgeting within Engineering [this will be in the form of 3 chapters]
4. a Glossary of terms and expressions [beginning to identify terminology of the mathematics and mechanical engineering discourse]- together with the Foundation Language lecturer.

Practicals will be added, with some reworking of:

1. data handling
2. the straight line and parabola
3. linear and quadratic equations
4. ratios percentages and proportions
5. areas and volumes
6. trigonometry.

Where possible, integration and support for Foundation drawing, Foundation Science , Manufacturing , Computer skills and Materials Science will also be considered.

OUTLINE FOR MATERIALS DEVELOPMENT FOR FOUNDATION SCIENCE

The context in which the current text book was written was that of a Foundation course that was only 6 months long, the Foundation course has now been extended to a year long course. This means that we are able to teach and do far more than was previously possible, but it also means that we require more hard copy resources – ie: a text book with a wider scope.

The proposal is to:

- cut back on some of the existing chapters (particularly the Chemistry),
- modify some of the existing chapters, primarily at this stage by adding more examples with answers, so that students have more problems to to practice with and are also able to grade themselves
- add new chapters that cover topics which are currently taught but not included in the present book. These chapters would comprise Moments, Centers of Gravity and a more-in depth chapter on units, measurement, unit conversions and so on.
- Integration with mathematics, drawing, computer and communication skills will also be considered.

The time-frame would be that the material will be developed from now and during the course of 2006 and trialed on the students of 2006. The new book then ought to be ready for the students of 2007.

Margot Lynn
23 September 2005

Proposed Contents For Foundation Drawing Book.

This text will serve both Chem Eng and Mechanical Engineering, having a generic and discipline specific sections. Attempts will be made to integrate with other Foundation subjects.

Additions to the contents of this book is highly likely.

1. Basic Principles Of Engineering Drawing
 - 1.1 Introduction
 - 1.2 Drawing As A Communication Tool
 - 1.3 Drawing Equipment And Paper
 - 1.4 Standard Materials
 - 1.5 Typical Notes Found On Drawings
 - 1.6 Typical Abbreviations Found On Drawings
 - 1.7 Standard Measurement
 - 1.8 Conventions Of Line Types
 - 1.9 Engineering Terminology
 - 1.10 Scales
 - 1.11 Application Of Drawing Equipment
 - 1.12 1D, 2D & 3D
 - 1.13 Printing
 - 1.14 Dimensioning
 - 1.15 Standard Drawing Symbols
2. Sketching
 - 2.1 Introduction
 - 2.2 Formation Of Sketches
 - 2.3 Sketch Applications
 - 2.4 Sketching Proportionally
 - 2.5 Sketching Techniques
3. Geometrical Construction
4. Orthographic Projection
5. Isometric Drawing

Chemical Drawing Additions

1. Kinds of Piping
2. Pipe Joints and Fittings
3. Pipe Drawing symbols
4. Pipe Drawings
5. Flow Diagrams
6. Drawing Using Chem Cad Software

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY

Communication Skills I	
COURSE CODE	
MKD100	
NQF Level: 6	Credits: 0.0
Faculty: Engineering	Department: Mechanical Engineering
Lecturer: F. Harris	Date: 2005
Qualification: National Diploma in Mechanical Engineering	

PURPOSE

To develop the ability to become competent and effective communicators in English
 To develop/enhance the ability to read with understanding.
 To develop the ability to write logically, clearly, concisely and correctly.
 To develop the ability to speak with confidence in a clear and correct manner.

Assessment Criteria / Exit Level outcomes:

You will know that you have met the outcomes of the course, when you are able to:

6. Read and understand Engineering and general English language texts
7. Write a logical, clear, concise piece of writing
8. Deliver an oral presentation

OUTCOMES	SUB - OUTCOMES
1. Read with Comprehension	<ul style="list-style-type: none"> • Recognise different types of texts • Identify/understand/interpret the meaning of words in a text • Build vocabulary and use a dictionary; • Infer meaning from context and define terms and concepts; • Display insight into the structure and logic of a text; • Read with a purpose and follow a writer's argument; • Interpret graphic information;

<p>2 Write clearly</p>	<ul style="list-style-type: none"> • Use basic structure of beginning, middle and ending; • Write effective beginnings and endings; • Link paragraphs logically in a piece of writing; • Link the introduction to the body of the writing; • Use topic and supporting sentences to construct coherent paragraphs; • Write coherent paragraphs using links and transitions; • Use style, register and tone appropriate to context and audience; • Produce an appropriate document in the engineering context. • Evaluate own and peers' writing.
<p>3. Apply grammatical structures and conventions in the context of reading and writing</p>	<ul style="list-style-type: none"> • Identify and use parts of speech, verb tenses, basic concord, pronoun reference, punctuation, word order, reported speech and passive voice; • Use grammatical rules to construct sentences correctly; • Identify grammatical problems in sentences and paragraphs; • Edit incorrect and inappropriate usage of own and peers' writing;
<p>4. Speak and listen to others</p>	<ul style="list-style-type: none"> • Organise and undertake group discussions; • Deliver a formal oral presentation appropriate to the audience and purpose; • Present relevant and logically organized content;

	<ul style="list-style-type: none"> • Prepare and integrate relevant and appropriate presentation media; • Interact with an audience and respond appropriately to questions; • Listen actively, attentively and purposefully; • Use body language to convey a message; • Use voice and language effectively.
5. Access / Collect information	<ul style="list-style-type: none"> • State the purpose for collecting information as a group or individually; • Identify the information needed for task completion as a group or individually; • Assign research roles and responsibilities for individual members in group contexts; • Manage group dynamics and diversity in group contexts; • Select, search for and locate the specified sources of information for the task; • Use the library and internet effectively • Retrieve and engage with (read, listen, view) the information.
6. Analyse information	<ul style="list-style-type: none"> • Identify the main ideas in a text and summarise the information; • Record the information in the form of notes; • Synthesise information in relation to the task.
7. Organise information	<ul style="list-style-type: none"> • Organise the information from multiple sources into a coherent

	<p>and logical structure within a given format;</p> <ul style="list-style-type: none"> • Apply the appropriate layout and writing conventions required by the task; • Understand plagiarism and how to avoid it; • Make inferences from the information; • Express own point of view in relation to the information; • Justify own point of view on the information; • Use the process approach for drafting and revising information to achieve a coherent and logically structured document;
<p>8. Evaluate and present information</p>	<ul style="list-style-type: none"> • Present the information as a written document that has a professional appearance and meets an acceptable standard; • Integrate graphic information into a document • Present the information orally for a given audience; • Evaluate the presented information against the stated task.

COURSE REQUIREMENTS

A course workbook will be handed to you.

Dictionaries will be provided. You may bring your own.

A writing file and a presentation file will be handed to you.

All written assignments must be submitted on the due date/s.

All drafts must be handed in with the final document.

All assignments must be checked and signed by a student assistant before it is submitted.

Oral presentation dates should be adhered to. No marks will be given to anyone who fails to do so.

SYLLABUS AND SCHEDULE

Semester 1

We ek	Topic
1	Introduction
2	Using a dictionary & a thesaurus
3	Building vocabulary
4	Reading and comprehension (various engineering texts)- ongoing
5	Listening and comprehending (ongoing)
6	Summarising (ongoing)
7	Basic essay structure
8	Writing introductions
9	Paragraph construction
10	Writing conclusions
11	planning an outline, drafting
12	revising editing
13	Grammatical structures in texts (ongoing)
14	Sentence construction
15	oral presentations (ongoing)
16	writing personal reflections (ongoing)

Semester 2

We ek	Topic
1	Reading and comprehension (various engineering texts)- ongoing
2	Listening and comprehending (ongoing)
3	Building vocabulary
4	Report writing
5	Graphic literacy
6	Grammatical structures in texts (ongoing)
7	Summarising
8	Producing written text in engineering context
9	planning an outline, drafting
10	revising editing
11	oral presentations (ongoing)
12	writing personal reflections (ongoing)

ASSESSMENT SCHEDULE:

Course evaluation is continuous, through formative and summative assessments, comprising eight evaluations made up as follows:

SEMESTER 1

ASSESSMENT	WEIGHTING	DATE
Assignment 1	10%	To be announced
Test 1	15%	To be announced
Oral Presentation	10%	
Projects	10%	

SEMESTER 2

ASSESSMENT	WEIGHTING	DATE
Assignment 2	15%	To be announced
Test 2	15%	To be announced
Oral Presentation	10%	
Projects	15%	

BELLVILLE CAMPUS:

LECTURER: F. Harris
Room 0121

NB! ANY QUERY REGARDING A MARK ALLOCATED FOR A TEST, MUST BE RAISED NOT LATER THAN ONE DAY AFTER RECEIVING THE SCRIPT. IT IS YOUR RESPONSIBILITY TO CHECK THAT THE MARKS YOU RECEIVE IN CLASS CORRESPOND WITH THAT ON THE PRINTED MARKSHEET. SUCH QUERIES SHOULD BE BROUGHT TO THE ATTENTION OF THE LECTURER WITHIN 7 DAYS OF NOTIFICATION.

Critical Cross Field Outcomes

1. Identifying and solving problems in which responses display that responsible decisions using critical and creative thinking have been made.
2. Working effectively with others as a member of a team, group, organisation or community.
3. Organising and managing oneself and one's activities responsibly and effectively.
4. Collecting, analysing, organising and critically evaluating information.
5. Communicating effectively using visual, mathematical and / or language skills in the modes of oral and / or written persuasions.
6. Using science and technology effectively and critically, showing responsibility towards the environment and the health of others.
7. Demonstrating an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation. (Systemic thinking).
8. Reflect on and explore a variety of strategies to learn more effectively.
9. Participate as responsible citizens in the life of local, national and global communities.
10. Be culturally and aesthetically sensitive across a range of social contexts.
11. Explore educational and career opportunities.
12. Develop entrepreneurial opportunities.

Applied Competence

Practical competence: The demonstrated ability to perform a set of tasks. We do not want technologist who understand and can talk about ways of doing but who cannot 'do'.

Foundational competence: Demonstrated understanding of what we or other practitioners are doing and why. We do not want technologists who when asked what they are doing and why respond: "I do not know, the manual says I have to do it this way".

Reflexive competence: Demonstrated ability to learn from our actions and to adapt to changes and unforeseen circumstances. We do not want technologists who are not flexible in their performances and who not have the capacity for independent thought and innovation (source ETDP report).

ECSA standards for accredited university engineering bachelors degrees (pe61)

A BSc (Eng) graduate is competent to:

1. Identify, assess, formulate and solve convergent and divergent engineering problems creatively and innovatively.
2. Apply knowledge of mathematics, basic sciences and engineering sciences from first principles to solve engineering problems.
3. Perform creative, procedural and non-procedural design and synthesis of components, systems, works, products or processes.
4. Apply research methods, plan and conduct investigations and experiments using appropriate equipment and analyse, interpret and derive information from data.
5. Use appropriate engineering methods, skills tools and assess the results they yield.
6. Communicate effectively, both orally and in writing, with engineering audiences and the community at large, using appropriate structure, style and graphical support.
7. And is critically aware of the impact of engineering activity on society and the environment, and the need to bring into the analysis and design considerations of the impact of technology on society and the personal, social, cultural values and requirements of those affected by engineering activity
8. Work effectively as an individual, in teams and in multidisciplinary environments showing leadership and performing critical functions.
9. Engage in lifelong learning through well developed learning skills.
10. Exercise judgement commensurate with knowledge and experience and critically aware of the need to act professionally and ethically and to take responsibility within own limits of competence.

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	45.96969697	44.7575758
Variance	104.280303	58.0018939
Observations	33	33
Pearson Correlation	-0.352490501	
Hypothesized Mean Difference	0	
df	32	
t Stat	0.472566857	
P(T<=t) one-tail	0.319864737	
t Critical one-tail	1.693888407	
P(T<=t) two-tail	0.639729474	
t Critical two-tail	2.036931619	

Comparing Matric maths with Physics for 2002 cohort

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	66.35897436	64.38461538
Variance	139.9203779	215.9271255
Observations	39	39
Pearson Correlation	0.697284456	
Hypothesized Mean Difference	0	
df	38	
t Stat	1.157610614	
P(T<=t) one-tail	0.127123791	
t Critical one-tail	1.685953066	
P(T<=t) two-tail	0.254247581	
t Critical two-tail	2.024394234	

Table comparing MAR100 and MIJ100 for 2002

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	68.32352941	52.38235294
Variance	107.6800357	260.3039216
Observations	34	34
Pearson Correlation	0.733554949	
Hypothesized Mean Difference	0	
df	33	
t Stat	8.403108426	
P(T<=t) one-tail	5.21434E-10	
t Critical one-tail	1.692360456	
P(T<=t) two-tail	1.04287E-09	
t Critical two-tail	2.03451691	

Comparing Foundation Maths and MARB10 for 2002 cohort

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	50.31707317	42.0487805
Variance	99.62195122	87.297561
Observations	41	41
Pearson Correlation	-0.104452405	
Hypothesized Mean Difference	0	
df	40	
t Stat	3.685120049	
P(T<=t) one-tail	0.000338697	
t Critical one-tail	1.683852133	
P(T<=t) two-tail	0.000677395	
t Critical two-tail	2.021074579	

Comparing Matric Mathematics with Physics for 2003 cohort

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	61.3877551	49.20408163
Variance	325.4090136	194.9158163
Observations	48	48
Pearson Correlation	0.86230308	
Hypothesized Mean Difference	0	
df	47	
t Stat	9.197322636	
P(T<=t) one-tail	1.82093E-12	
t Critical one-tail	1.677224197	
P(T<=t) two-tail	3.64187E-12	
t Critical two-tail	2.010634722	

Table comparing MAR100 and MIJ100 for 2003

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	64.88888889	66.35555556
Variance	184.2373737	271.3252525
Observations	45	45
Pearson Correlation	0.894916304	
Hypothesized Mean Difference	0	
df	44	
t Stat	-1.321960358	
P(T<=t) one-tail	0.096506574	
t Critical one-tail	1.680230071	
P(T<=t) two-tail	0.193013148	
t Critical two-tail	2.0153675	

Comparing Foundation Maths with MARB10 for 2003 cohort

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	46.72222222	42.08333
Variance	89.92063492	164.8214
Observations	36	36
Pearson Correlation	-0.327432307	
Hypothesized Mean Difference	0	
df	35	
t Stat	1.521911207	
P(T<=t) one-tail	0.068507891	
t Critical one-tail	1.68957244	
P(T<=t) two-tail	0.137015782	
t Critical two-tail	2.030107915	

Comparing Matric Maths vs Physics 2004

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	54.33333333	45.35714286
Variance	293.7886179	346.1376307
Observations	42	42
Pearson Correlation	0.845920167	
Hypothesized Mean Difference	0	
df	41	
t Stat	5.805230331	
P(T<=t) one-tail	4.09329E-07	
t Critical one-tail	1.682878003	
P(T<=t) two-tail	8.18659E-07	
t Critical two-tail	2.019540948	

Table comparing MAR100 and MIJ100 for 2004

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	64.15	62.1
Variance	183.6078947	304.5157895
Observations	20	20
Pearson Correlation	0.546601886	
Hypothesized Mean Difference	0	
df	19	
t Stat	0.605000232	
P(T<=t) one-tail	0.276168396	
t Critical one-tail	1.729131327	
P(T<=t) two-tail	0.552336792	
t Critical two-tail	2.093024705	

Comparing Foundation Mathematics with MARB10 for 2004 cohort

t-Test: Paired Two Sample for Means

	<i>Variable</i>	
	<i>Variable 1</i>	<i>2</i>
Mean	50.90625	44.5
Variance	173.3135081	43.6129
Observations	32	32
	-	
Pearson Correlation	0.005751039	
Hypothesized Mean Difference	0	
df	31	
t Stat	2.454844223	
P(T<=t) one-tail	0.009953299	
t Critical one-tail	1.695518742	
P(T<=t) two-tail	0.019906597	
t Critical two-tail	2.039513438	

Comparison Matric Maths vs Physics 2005

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	60.57894737	52.31579
Variance	124.5746799	144.7624
Observations	38	38
Pearson Correlation	0.714681496	
Hypothesized Mean Difference	0	
df	37	
t Stat	5.790287079	
P(T<=t) one-tail	6.03815E-07	
t Critical one-tail	1.687093597	
P(T<=t) two-tail	1.20763E-06	
t Critical two-tail	2.026192447	

Table comparing MAR100 and MIJ100 for 2005

t-Test: Paired Two Sample for Means

	<i>Variable 1</i>	<i>Variable 2</i>
Mean	65.82758621	57.34482759
Variance	84.50492611	134.5197044
Observations	29	29
Pearson Correlation	0.55596047	
Hypothesized Mean Difference	0	
df	28	
t Stat	4.557342048	
P(T<=t) one-tail	4.64696E-05	
t Critical one-tail	1.701130259	
P(T<=t) two-tail	9.29391E-05	
t Critical two-tail	2.048409442	

Comparing Foundation Mathematics with MARB10 for 2005 cohort

CAPE PENINSULA UNIVERSITY OF TECHNOLOGY
STUDENT COUNSELLING
BELLVILLE

**Report on the identification of risk factors for Mechanical Engineering
(Foundation) 2005**

This investigation was done with students from the Mechanical Engineering foundation year and forms part of a wider research that focuses on the identification of possible risk factors that impact on students' studies as well as retention and throughput at CPUT. The aim of the report is to provide a summary of possible risk factors that might contribute to students' poor academic performance and affect retention rates on campus.

The following information was extracted from the at risk factor survey that was conducted with a total of 15 Mechanical Engineering (foundation) students. The results are subdivided into academic and non academic factors.

Academic factors

The descriptive statistics show that more than 80% of students are aware of additional supplemental instruction but only 26.7% attend additional tutorial classes in subjects they find difficult. 80% of the students indicated they do not belong to an informal study group and they do not have effective study skills. 53.3% indicated they do not know how to study effectively and need some intervention in exam writing skills.

Non-Academic factors

The descriptive statistics show that non-academic factors play a role in student retention and throughput. 80% of the students indicated that they have been informed about the student support and development services on campus but only 26% of the students feel positive and confident to make use of the support services. More than 50% indicated that they are not following a healthy and nutritious lifestyle, no regular balanced meals daily. Non-academic factors such as not utilizing support services could be seen as at risk factors that could play a role in student retention and throughput.

Contact student counselling (Bellville) for more information regarding counselling/learner support for students at risk

15 March 2005

2003 CLASS TIMETABLE**DEPARTMENT: Mechanical****CLASS: FOUNDATION**

DAY	1	2	3	4	5	6	7	8	9	10	11
	08H25	09H05	09H45	10H25	11H05	11H45	12H25	13H30	14H00	14H40	15H20
M	MKD100	MKD100		MES010	MES010	MES010	MIJ100	LUNCH BREAK * LUNCH BREAK	MCPR10	MCPR10	MCPR10
T	MIJ100	MIJ100			MES010	MES010			MAR100	MAR100	MAR100
W	MAR100	MAR100	MKD100	MKD100					MKD100	MKD100	MKD100
T	MIJ100	MIJ100	MAR100	MAR100	MKD100	MKD100	MKD100		MIJ100	MIJ100	MIJ100
F	MES010	MES010	MKD100	MKD100	MAR100	MAR100					

2004 CLASS TIMETABLE

DEPARTMENT: Mechanical

CLASS: FOUNDATION

	1	2	3	4	5	6	7	8	9	10	11
	08H25	09H05	09H45	10H25	11H05	11H45	12H25	13H30	14H00	14H40	15H20
AY	MKD100	MKD100	MES010	MES010	MIJ100	MIJ100	MIJ100	LUNCH BREAK * LUNCH BREAK	MKD100	MKD100	MKD100
M	MIJ100	MIJ100	MKD100	MKD100	MES010	MES010	MES010		MMD100	MMD100	MMD100
T	MAR100	MAR100	MKD100	MKD100							
W	MAR100	MAR100	MIJ100	MIJ100	MMD100	MMD100	MMD100				
F	MES010	MES010	MAR100	MAR100	MKD100	MKD100					

Matric Mathematics Grade 2002

		Frequency	Percent	Valid Percent	Cumulative percent
	LG	0	0	0	0
	SG	33	84.6	100	100
	HG	0	0	0	100
Valid	Total	33	84.6		
Missing	System	6	15.6		
	Total	39	100		

Matric mathematics Symbol 2002

		Frequency	Percent	Valid Percent	Cumulative percent
	G	1	2.5	3	3
	F	7	17.9	21.2	24.2
	E	14	35.9	42.4	66.6
	D	8	20.6	24.3	90.8
	C	3	7.6	9.1	100
	B	0	0	0	100
Valid	Total	33	84.5	100	
missing	system	6	15.5		
	Total	39	100		

Matric Physics Grade 2002

		Frequency	Percent	Valid Percent	Cumulative percent
	LG	0	0	0	0
	SG	32	82	97	97
	HG	1	2.5	3	100
Valid	Total	33	84.5		
Missing	System	6	15.5		
	Total	39	100		

**Matriculation
symbols
Physics
2002**

		Frequency	Percent	Valid Percent	Cumulative percent
	G	1	2.5	3	3
	F	7	17.9	21.2	24.2
	E	17	43.6	51.5	75.7
	D	6	15.5	18.2	93.9
	C	2	5	6.1	100
Valid	Total	33	84.5		
missing	system	6	15.5		
	Total	39	100		

Matric English Grade 2002

		Frequency	Percent	Valid Percent	Cumulative percent
	SG	0	0	0	0
	HG 2nd				
	L	30	76.9	90.9	90.9
	HG 1st L	3	7.6	9.1	100
Valid	Total	33	84.5	100	
Missing	System	6	15.5		
	Total	39	100		

Matric English Symbol 2002

		Frequency	Percent	Valid Percent	Cumulative percent
	G	0	0	0	0
	F	4	10.3	12.1	12.1
	E	13	33.3	39.4	51.5
	D	12	30.8	36.4	87.9
	C	3	7.6	9.1	97
	B	1	2.5	3	100
Valid	Total	33	84.5	100	
missing	system	6	15.5		
	Total	39	100		

Matric Mathematics Grade 2003

	Frequency	Percent	Valid Percent	Cumulative percent
LG	0	0	0	0
SG	40	83.3	100	100
HG	0	0	0	100
Valid Total	40	83.3	100	
Missing System	8	16.7		
Total	48	100		

Matric mathematics Symbol 2003

	Frequency	Percent	Valid Percent	Cumulative percent
G	1	2.1	2.5	2.5
F	3	6.3	7.5	10
E	18	37.5	45	55
D	9	18.7	22.5	77.5
C	9	18.7	22.5	100
B	0	0	0	100
Valid Total	40	83.3	100	
missing system	8	16.7		
Total	48	100		

Matric Physics Grade 2003

	Frequency	Percent	Valid Percent	Cumulative percent
no physics	1	2.1	2.5	2.5
LG	0	0	0	2.5
SG	39	81.2	97.5	100
HG	0	0	0	100
Valid Total	40	83.3	100	
Missing System	8	16.7		
Total	48	100		

Matric Physics Symbol 2003

	Frequency	Percent	Valid Percent	Cumulative percent
No physics	1	2.1	2.5	2.5
G	0	0	0	2.5
F	9	18.7	22.5	25
E	23	47.9	57.5	82.5
D	6	12.5	15	97.5
C	1	2.1	2.5	100
Valid Total	40	83.3	100	
missing system	8	16.7		
Total	48	100		

Matric English Grade 2003

	Frequency	Percent	Valid Percent	Cumulative percent
SG	0	0	0	0
HG 2nd L	28	58.3	70	70
HG 1st L	12	25	30	100
Valid Total	40	83.3	100	
Missing System	8	16.7		
Total	48	100		

Matric English Symbol 2003

	Frequency	Percent	Valid Percent	Cumulative percent
G	0	0	0	0
F	4	8.3	10	10
E	11	22.9	27.5	37.5
D	14	29.2	35	72.5
C	9	18.7	22.5	95
B	2	4.2	5	100
Valid Total	40	83.3	100	
missing system	8	16.7		
Total	48	100		

Matric Mathematics Grade 2004

	Frequency	Percent	Valid Percent	Cumulative percent
LG	0	0	0	0
SG	33	78.6	100	100
HG	0	0	0	100
Valid Total	33	78.6	100	
Missing System	9	21.4		
Total	42	100		

Matric mathematics Symbol 2004

	Frequency	Percent	Valid Percent	Cumulative percent
G	0	0	0	0
F	11	26.2	33.3	33.3
E	13	30.9	39.4	72.7
D	7	16.7	21.2	93.9
C	2	4.8	6.1	100
B	0	0	0	100
Valid Total	33	78.6	100	
missing system	9	21.4		
Total	42	100		

Matric Physics Grade 2004

	Frequency	Percent	Valid Percent	Cumulative percent
no Physics	1	2.4	2.9	2.9
LG	0	0	0	2.9
SG	33	78.6	97.1	100
HG	0	0	0	100
Valid Total	34	81	100	
Missing System	8	19		
Total	42	100		

Matric Physics Symbol 2004

	Frequency	Percent	Valid Percent	Cumulative percent
No Physics	1	2.4	2.9	2.9
G	0	0	0	2.9
F	8	19	23.5	26.4
E	21	50	61.8	88.2
D	3	7.2	8.9	97.1
C	1	2.4	2.9	100
Valid Total	34	81	100	
missing system	8	19		
Total	42	100		

Matric English Grade 2004

	Frequency	Percent	Valid Percent	Cumulative percent
SG	0	0	0	0
HG 2nd L	27	64.3	79.4	79.4
HG 1st L	7	16.7	20.6	100
Valid Total	34	81	100	
Missing System	8	19		
Total	42	100		

Matric English Symbol 2004

	Frequency	Percent	Valid Percent	Cumulative percent
G	0	0	0	0
F	2	4.8	5.9	5.9
E	15	35.8	44.1	50
D	9	21.4	26.5	76.5
C	8	19	23.5	100
B	0	0	0	100
Valid Total	34	81	100	
missing system	8	19		
Total	42	100		

Matric Mathematics Grade 2005

	Frequency	Percent	Valid Percent	Cumulative percent
LG	0	0	0	0
SG	32	82.1	100	100
HG	0	0	0	100
Valid Total	32	82.1	100	
Missing System	7	17.9		
Total	39	100		

Matric mathematics Symbol 2005

	Frequency	Percent	Valid Percent	Cumulative percent
G	2	5.1	6.3	6.3
F	4	10.3	12.5	18.8
E	9	23.2	28.1	46.9
D	7	17.9	21.9	68.8
C	7	17.9	21.9	90.7
B	3	7.7	9.3	100
Valid Total	32	82.1	100	
missing system	7	17.9		
Total	39	100		

Matric Physics Grade 2005

	Frequency	Percent	Valid Percent	Cumulative percent
No Physics	0	0	0	0
LG	0	0	0	0
SG	32	82.1	100	100
HG	0	0	0	100
Valid Total	32	82.1	100	
Missing System	7	17.9		
Total	39	100		

Matric Physics Symbol 2005

	Frequency	Percent	Valid Percent	Cumulative percent
No Physics	0	0	0	0
G	0	0	0	0
F	7	17.9	21.9	21.9
E	19	48.7	59.4	81.3
D	5	12.8	15.6	96.9
C	1	2.7	3.1	100
Valid Total	32	82.1	100	
missing system	7	17.9		
Total	39	100		

Matric English Grade 2005

	Frequency	Percent	Valid Percent	Cumulative percent
SG	0	0	0	0
HG 2nd L	30	76.9	93.8	93.8
HG 1st L	2	5.2	6.2	100
Valid Total	32	82.1	100	
Missing System	7	17.9		
Total	39	100		

Matric English Symbol 2005

	Frequency	Percent	Valid Percent	Cumulative percent
G	0	0	0	0
F	7	17.9	21.9	21.9
E	15	38.5	46.9	68.8
D	6	15.4	18.7	87.5
C	4	10.3	12.5	100
B	0	0	0	100
Valid Total	32	82.1	100	
missing system	7	17.9		
Total	39	100		

PENINSULA TECHNIKON (HIGHER DEGREES COMMITTEE)



POSTGRADUATE APPLICATION FORM

SECTION A: PARTICULARS OF STUDENT					
Surname		First names		Gender (M/F)	M
Date of Birth (YY/MM/DD)	1963/07/20	Citizenship	SA	ID number	
Address during period of study					
Department	Education	Student No.		Full / Part time	Part time
Course Code (e.g. MTECME)	Mtech[Mech]	Commencement Date		2005	

SECTION B: PARTICULARS OF RESEARCH PROJECT			
Title of research project	An Evaluation of Mathematics within an Engineering Foundation Programme		
If this is part of a wider Technikon research project, indicate the name of this research project:			
Work Integrated Learning Research Unit			
Internal Supervisor/Promoter			
Name	Professor Christine Winberg	Qualifications	PhD (Language)
External/Co- Supervisor/Promoter			
Name	Graeme Oliver	Qualifications	DTech Science[Polish Academy of Science]
Institution	CPUT	Position	Research Head Dept of Mechanical Engineering CPUT [Bellville campus]

SECTION C: QUALIFICATIONS			
Degree / Diploma	Institution	Year	Field of Study
BSc	UCT	1984	Mathematics and Physical Science
PGCE	UCT	2002	Diploma in Mathematics and Physical Science Education

SECTION D: EMPLOYMENT HISTORY		
Employer	Position	Period employed

SECTION E: PUBLICATIONS
JEDT Dec 2004 [unreviewed paper – TOWARDS A THEORETICAL FRAMEWORK FOR ANALYZING TEACHING AND LEARNING ON AN ENGINEERING FOUNDATION PROGRAMME]

Signature of student		Date	21.01.05
Signature of supervisor		Date	21.01.05
ATTACHMENTS			
Certified proof of entrance qualification (e.g. for MTECH, attach copy of B.Sc. (Eng.) or BTech degree)			On file with HR
Brief outline of research to be undertaken (250 words)			See below

RECOMMENDATIONS			
Chairman: Faculty Research Committee		Date	.05
Chairman: Higher Degrees Committee		Date	.05

Please add comments below, if necessary.

1. **Title:** An evaluation of Mathematics within an Engineering Foundation Programme
2. **Background:** Ten years into a democracy, SA still faces many developmental challenges. Increasing the throughput of graduates and improving the quality of Science and Engineering programmes is one of the ways of meeting these developmental challenges. Since 2002 Universities of technology have introduced Foundation programmes as a key mechanism for increasing throughput and enhancing quality of Science and Engineering programmes. This is consistent with the National Education policy, which since 2005, is funding these programmes. This study will evaluate an aspect of a Foundation programme in Mechanical Engineering, with a view to contributing to its improvement.
3. **Problem statement:** This study evaluates the Mathematics component of a Foundation programme in a Mechanical Engineering Department, for the purpose of improving the programme. The use of both quantitative and qualitative evaluation methodologies will be used.

Sub-problem 1: How was Mathematics in the Foundation Programme conceptualised and designed?

Sub-problem 2: How was the Mathematics component of the Foundation programme implemented?

Sub-problem 3: What was the impact of the Mathematics component of the Foundation Programme on student achievement?

4. **Rationale:** The evaluation of Foundation programmes is necessary if they are to meet their stated objectives: “ *The development of human resources is fundamental to socio-economic upliftment and meeting the challenges of our new democracy. The demand on higher education to enrol under-prepared students who meet the minimum requirements will remain a factor in the short to medium term. The key objectives for the development and provision of foundation projects and associated support systems are:*

- *To increase retention and throughput in identified programmes while ensuring quality*
- *To develop appropriate skills and experience for learners*
- *To develop a basic understanding of what an academic/professional career entails*
- *Orientation and preparing independent learners for Higher Education and Lifelong learning... ”* (Application to Dept of Education for Foundation Programme Grant 2004/5-2006/7; 31 March 2004; Peninsula Technikon).

5. **Research Objectives:**

- To contribute to a formative process of programme development and enhancement
- To offer guidelines for improving the Mathematical component of Foundation Programmes in an engineering context

6. **Delimitations of the Research:** This study focuses on curricula, as well as staff and student participation in the Foundation Programme of the Mechanical Engineering Department of CPUT (Bellville Campus) between 2002 – 2005.

7. **Methodology:** The evaluation research design addresses the conceptualisation, design, implementation and impact of the programme under investigation (Babbie and Mouton, 2001). Data will be obtained from curricular documents, students’ mark records, questionnaires and individual and focus group interviews. Statistical analyses methods will be applied to course results. Verbal data will be analysed following Geisler’s (2003) system of coding for thematic interpretation.

8. **Ethical issues:** It is incumbent on the researcher to maintain the highest ethical standards in conducting the research. This goes beyond guaranteeing confidentiality, and informed consent, and extends to include using sensitive methods that in no way negatively impacts on the performance and integrity of the students and lecturers taking part in this evaluation.

NB: A full research proposal should be submitted to the Higher Degrees Committee via the Faculty Research Committee before the end of May of the student’s first year of registration. This proposal should be in accordance with the research proposal guidelines in the Research Procedure Manual for Masters and Doctoral student, which is available from the Research Co-ordinator’s office.

1. Cape Peninsula University of Technology

2. Diploma in Mechanical Engineering

3.1 Qualification title

Diploma in Mechanical Engineering [Extended Curriculum]

3.2 Duration

3 ½ –4 years

3.3 Admission criteria

50 % maths SG; 50% Physical Science SG ; 40% English 1st language or 2nd language HG. Other prospective applicants who have these subjects but do not meet the minimum level but are in possession of a matriculation certificate or equivalent qualification, allowing them access into the institution, may be admitted, subject to an interview with a Mechanical Engineering Department appointed representative.

3.4 Foundation qualification descriptions

Study time is minimum of four years though students may be promoted to the fast stream after the completion of year 1, ie the equivalent of S1 in the NDIPME.

Subjects and credit structure

Three year diploma with the regular first year curriculum extended over two years									
Academic year	Required courses						Credit values in year		
							Foundation	Regular	Total
Year 1 S1	Foundation Maths 1A [equivalent to MAR B10]	Foundation Mechanics [equivalent to MIJ010]	Foundation drawing [equivalent to MMD010]	Foundation Communication skills [equivalent to MKDS10]	Foundation manufacturing [equivalent to MIE010]	Foundation Computer skills [equivalent to MCPR10]			
Year 1 S2									

Year 2 S3	Maths 2A + sppt	Mechanics 2A + sppt.	Strengths 2+ support			
Year 2 S4	Fluids 2 + sppt	Manufacturing 2 + sppt.	Comm. 2B + sppt.			
Year 3 S5	Normal S 3					
Year 3 S6	Normal S 4					
Total credits for the diploma						

