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A model for developing undergraduate engineering mechanics education

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Abstract

This study explores the multitude of factors contributing to high fail rates among students studying first year engineering Mechanics, where fail rates in the order of 20-40% are common and persist across cohorts. Previous studies in the field of engineering Mechanics education have tended to focus on particular issues in the teaching and learning experience, or learning specific topic areas. The purpose of this study was to develop a more holistic understanding of first year engineering Mechanics education than has been conducted to date.

The research examined learning and teaching in first year engineering Mechanics courses at the University of Wollongong, The University of Tasmania, the University of Technology, Sydney, and the Australian Maritime College at UTAS. Multiple research methods were used to explore teaching and learning in Mechanics, separated into five lines of investigation. These lines of investigation were informed by five research sub-questions:

- What are students expected to learn in first year engineering Mechanics?
- What are the key topic areas students have difficulty with?
- What is the relationship between students' academic history and their achievement in Mechanics?
- What are the views of students and academics on first year engineering Mechanics education?
- How do students engage with new and different options for learning Mechanics?

Each of these lines of investigation offered different perspectives on the issue of high fail rates in Mechanics. The research was underpinned by Biggs' 3P (Presage, Process, Product) model of teaching and learning. The 3P model provided a framework for identifying possible relationships between the various issues identified in each of the five areas of investigation. Research findings were mapped to the 3P model to create a holistic understanding of the many factors contributing to high fail rates in first year Mechanics courses.

Mapping of research findings to the 3P model identified significant weaknesses in engineering Mechanics education in terms of its ability to support a wide array of student learning needs, and in the management of students and educators expectations of the teaching and learning process. This mapping process also identified a number of limitations in the 3P model itself.

This thesis proposes a revised 3P model that takes into account the complexities and contextual influences that are evident in Mechanics education. The revised 3P-student responsive model, abbreviated to 3P-sr, provides a framework for designing engineering Mechanics education that is based on evidence drawn directly from Mechanics education. The 3P-sr model creates a clearer representation of the influences and possible interactions between student and teacher-controlled aspects of the educational process. It emphasises the cyclic nature of teaching and learning in Mechanics, and reflects the need for a more purposeful and flexible interaction between student and teacher. The model provides a guide for the future development of engineering Mechanics courses that are more flexible, and responsive to the wide ranging learning needs of students studying Mechanics that were identified in this research. Whilst the 3P-sr model is not tested in this research, its development from the wide range of evidence presented in this mixed-methods research represents a novel contribution to addressing the problem of high fail rates in engineering Mechanics courses.

Declaration

I confirm that the work presented in this thesis is my own. Any contributions made by other researchers have been acknowledged in-text. This work has not been submitted to any other institution for award of a degree or other qualification.

Mr. Thomas Lachlan Goldfinch

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Key Terms

Course	A single course of study within a degree program (e,g, ENGG152)
Degree program	A series of course to be completed for the award of a Bachelor level degree in Australia
Engineering Mechanics	The study of mechanical forces and their effect on rigid bodies and particles (full definition, see 1.1)
Fail	An overall mark below 50%
Fail rate or failure rate	The proportion of a course cohort achieving and overall assessment mark below 50%
Mechanics	As per ‘Engineering Mechanics’
Pass	An overall assessment mark at or above 50%

List of Publications

The following is a list of publications relating directly to the research presented in this thesis:

Goldfinch, T., A. Carew and G. Thomas (2011). Students Views on Engineering Mechaincs Education and the Implications for Educators. *Engineering Education: an Australian Perspective*. S. Grainger and C. Kestell. Brentwood, UK, Multi-science Publishing.

Thomas, G., A. Henderson and T. Goldfinch (2011). The influence of university entry scores on student performance in engineering Mechanics. A*ustralasian Journal of Engineering Education 17(1).*

Goldfinch, T. and A. Gardner (2010). The wheel has already been invented: facilitating students' use of existing Mechanics resources. *Engineering Education. Birmingham, UK.*

McCarthy, T. and T. Goldfinch (2010). Teaching the Concept of Free Body Diagrams *Australasian Association for Engineering Education Conference. Sydney, NSW.*

Goldfinch, T., A. Carew and T. McCarthy (2009). A Knowledge Framework or Analysis of Engineering Mechanics Exams. *Research in Engineering Education Symposium. Palm Cove, QLD.*

Goldfinch, T., A. Carew and G. Thomas (2009). Students Views on Engineering Mechanics Education and the Implications for Educators. *20th Annual Conference for the Australasian Association for Engineering Education. Adelaide, SA.*

Thomas, G., A. Henderson, et al. (2009). The Influence of University Entry Scores on Performance in Engineering Mechanics. *20th Annual Conference for the Australasian Association for Engineering Education. Adelaide, SA.*

Goldfinch, T., A. Carew and T. McCarthy (2008). Improving Learning in Engineering Mechanics: The Significance of Understanding. *19th Annual Conference for the Australasian Association for Engineering Education. Yeppoon, QLD.*

Goldfinch, T., A. Carew, et al. (2008). Cross-institutional Comparison of Mechanics Examinations: A Guide for the Curious. *19th Annual Conference for the Australasian Association for Engineering Education. Yeppoon, QLD.*

Prusty, B. G., C. Russell, R. Ford, D. Ben-Naim, S. Ho, Z. Vrcelj, N. Marcus, T. McCarthy, T. Goldfinch, R. Ojeda, A. Gardner, T. Molyneaux and R. Hadgraft (2011). Adaptive tutorials to target Threshold Concepts in Mechanics – a community of practice approach. *Australasian Association for Engineering Education Annual Conference. Freemantle, WA.*

Chapter 1
Introduction

1.1 Background

Introductory Engineering Mechanics is a key foundation topic of study in many engineering disciplines, including Civil, Mechanical, Mining, Materials, Environmental, Mechatronics and Maritime engineering. It is a subject area in undergraduate curricula that typically involves the application of Newtonian physical principles in the analysis of rigid (i.e. Non-deformable), bodies and particles. Introductory Mechanics is generally separated into two major areas of study:

> **Statics**, which deals with objects at rest, or as it is termed 'static equilibrium'. This includes the analysis of common stationary structures such as beams and trusses. The theories and concepts of static Mechanics are the foundations for the design of all structures in the built environment.

> **Dynamics**, which deals with moving objects under the influence of applied forces. Introductory dynamics deals predominantly with particles in motion and forms the foundations for later studies in machine design, fluid Mechanics, and structural dynamics. The theories and methods introduced in dynamics underpin the design of all manner of machines and objects that involve moving components.

The topics covered in introductory Mechanics courses form the basis of many later topics of study, and are of particular significance for Civil and Mechanical engineers. The study of Mechanics typically makes up approximately 25% of the first year of engineering degree programs and up to 40% of the second year of the degree, depending on the discipline of engineering. A sound understanding of introductory engineering Mechanics is critical for related studies later in Bachelor of Engineering degree programs.

It is well known that many engineering students experience significant difficulties with introductory Mechanics. At the University of Wollongong, University of Technology, Sydney, and University of Tasmania, the rates of failure in first year Mechanics subjects typically range from 20-50% of the class (see data presented in 3.1.1). These failure

rates fluctuate from year-to-year but it was clear that at these institutions, the problem persisted across cohorts. The international engineering education literature also contains many examples of engineering educators who have worked to improve student learning where success in Mechanics had been identified as a problem (Ates & Cataloglu, 2007; Hestenes, Wells, & Swachhamer, 1992; Philpot, Hall, Hubing, & Campbell, 2005; Paul Steif, 2004; Paul Steif & Naples, 2003; Streveler, et al., 2006). It was clear that poor student performance in fundamental engineering Mechanics is a widespread and persistent problem.

These high rates of failure were potentially contributing to several issues in engineering education. Studies by Suresh (2006), Vogt (2008), Baillie and Fitzgerald (2000), Tyson (2011), and Marra et al (2012) all suggest that while non-academic factors such as loss of interest, failure to identify with the profession, and financial factors were the key factors in student attrition, barrier or gatekeeper courses such as Mechanics and calculus could contribute to the problems reported by students that do not complete their engineering degree. The potential impact of high fail rates on student retention in engineering was becoming increasingly of concern in Australian engineering education, along with the current skills shortages in professional engineering disciplines and the associated demand for graduates (King, 2008). In addition to retention issues, these high fail rates were impacting negatively on students' progression and on-time degree completion. The subsequent financial burden of student loans or upfront payments for repeated courses was also of concern.

High failure rates in first year Mechanics also appeared to flow on to second and third year engineering Mechanics courses where high rates of failure continued (see 3.1.1). This indicated that in addition to high failure rates, the quality and depth of learning in Mechanics overall was an issue. It was clear that further investigation of student learning in engineering Mechanics was needed to provide insights into this widespread and complex problem.

1.2 Purpose Statement and Research Question

The purpose of this study was to create a more complete understanding of first year engineering Mechanics education in courses where low pass rates persist. The research explores learning and teaching in Mechanics through a series of different perspectives, including student, staff, curriculum, and context. These perspectives were then used to

propose a new direction for Mechanics education that takes into account the multitude of factors contributing to low pass rates.

This exploration was conducted using multiple research methods applied to different focus areas. This approach sought to identify the various factors contributing to high failure rates, and possible interrelationships between factors. The research approach aimed to develop a more comprehensive and holistic understanding of teaching and learning in engineering Mechanics.

The overarching research question that this thesis sought to answer was:

What are the factors contributing to high fail rates in first year engineering Mechanics?

1.3 Thesis Overview

The multiple paths of investigation undertaken in this research resulted in a thesis structure that differs from the norm somewhat. Each path of investigation utilised different research methods suited to particular research sub-questions to explore teaching and learning in first year Mechanics. This research strategy is described visually in figure 1.1.

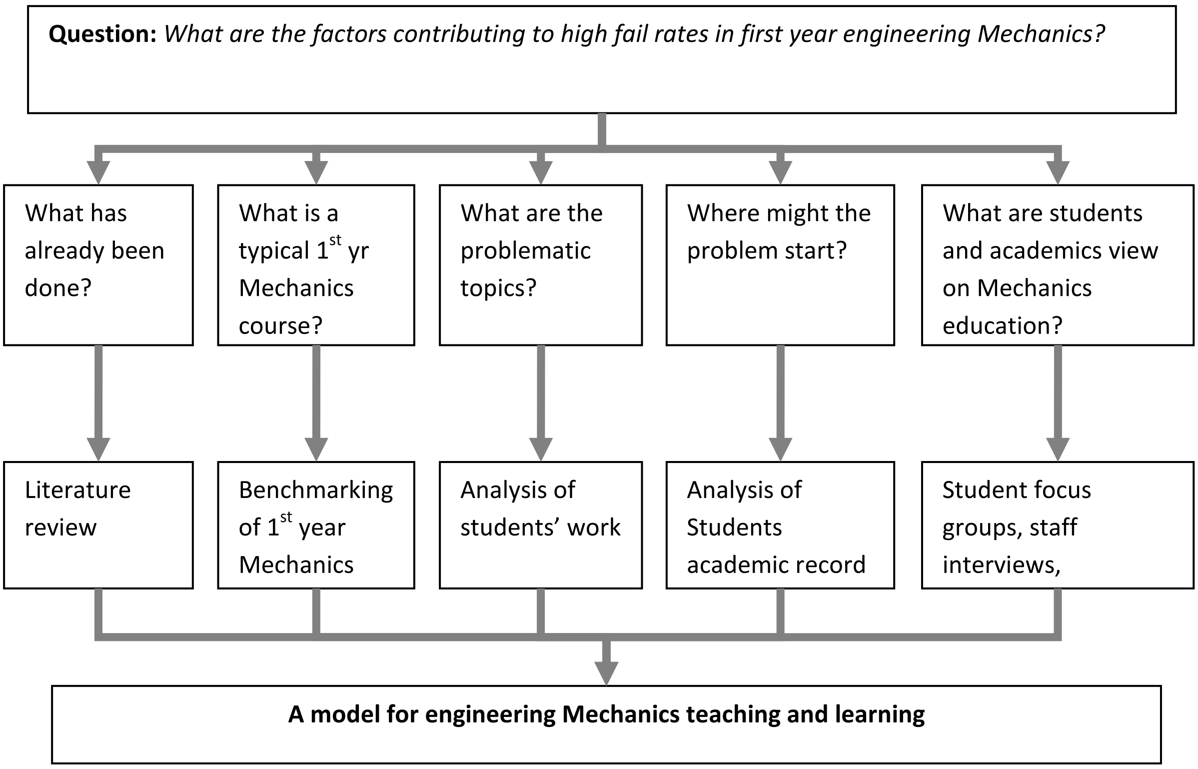


Figure 1.1 Diagrammatic representation of the research strategy

To address each sub-question, each research chapter contains distinct introduction, method, results, and summary sections. To develop a holistic understanding of teaching and learning in engineering Mechanics, the thesis is underpinned by John Biggs' 3P model of teaching and learning (see fig. 1.2). At the conclusion of each line of research, findings are linked back to the 3P model to create an understanding of the interrelationship between the factors identified.

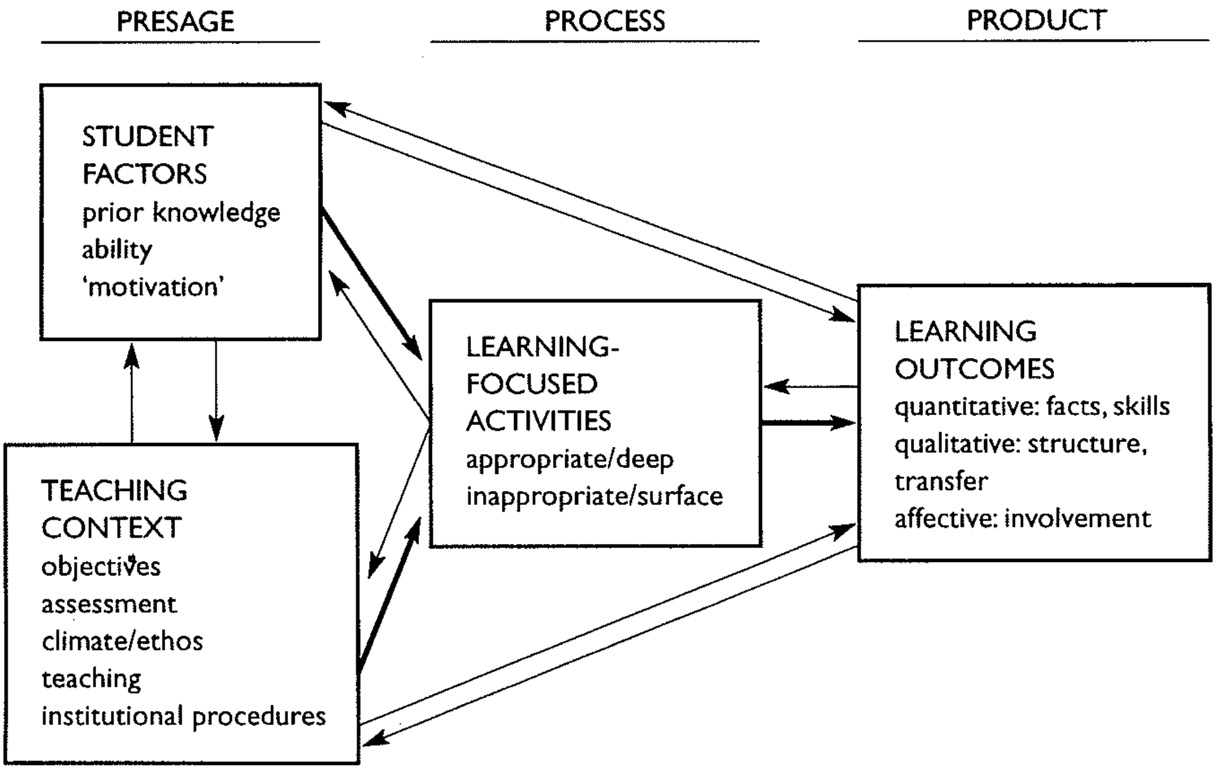


Figure 1.2 Biggs 3P model (Biggs, 1999, p. 18)

The lines of investigation in this study were guided by a number of research sub-questions. These questions set the focus for each chapter and research approach. These sub-questions and chapters are:

- Chapter 2: How have others approached the challenge of engineering Mechanics education?
- Chapter 3: What are students expected to learn in first year engineering Mechanics?

- Chapter 4: What are the key topic areas students have difficulty with?
- Chapter 5: What is the relationship between students' academic history and their achievement in Mechanics?
- Chapter 6: What are the views of students and academics on first year engineering Mechanics education?
- Chapter 7: How do students engage with new and different options for learning Mechanics?
- Chapter 8: What model of teaching and learning could be used in the design of engineering Mechanics courses?

Chapter two presents an exploration of the literature relating to engineering Mechanics education. The chapter establishes a foundational body of information from which the research direction of the thesis was determined. The review draws predominantly from the engineering education literature with a focus on previous work in engineering Mechanics education. Chapter two identified a range of themes apparent in the literature and how little progress has been made in improving Mechanics educational outcomes. The review justified the holistic approach to exploring Mechanics education that was taken in this research.

Chapter three details a benchmarking exercise that was conducted to identify common first year Mechanics subject content and the expectations of what students need to know in Mechanics. This chapter compares first year Mechanics courses from four different engineering schools at UOW, UTS, UTAS and AMC@UTAS. The work in this chapter also detailed the context of Mechanics education and common pedagogy and assessment approaches.

Chapter four objectively quantifies the particular topics students have difficulties with. The chapter investigates whether there are universal truths about the most problematic topics, and if so, what topics these are. A theoretical framework based on Romiszowski's knowledge schema (Goldfinch, Carew, & McCarthy, 2009; Romiszowski, 1981) was used for the analysis of Mechanics examination questions and students responses to them. A substantial set of data from students' actual work details the range challenges experienced by students at the topic level.

Chapter five considers the relationships between students' academic preparedness and performance in Mechanics that are commonly raised in the literature and in student and staff viewpoints collected in chapter six. This quantitative work compared students' academic achievements in related and unrelated areas of study to their achievements in Mechanics.

Chapter six explores the viewpoints of students and staff on the current state of engineering Mechanics education. Semi structured interviews with academics involved in teaching Mechanics were contrasted with the views of students drawn from small focus groups. The result of this component of the research was a detailed snapshot of Mechanics education from a variety of viewpoints. This work reiterated many of the common themes evident in the literature and provided some interesting insights into teaching and learning in engineering Mechanics.

Chapter seven builds upon the findings of the literature in chapter 2 and some of the outcomes of chapter 6. Chapter 7 presents an observational study of how students engage with a variety of online learning resources in an independent study setting. This component of the research explored whether online learning resources had the potential to address some of the issues raised by students and staff. The outcomes of this work supported the model of teaching and learning for Mechanics proposed in chapter 8.

Chapter eight, the final chapter, considers the findings of all of these lines of investigation in terms of Biggs' 3P model of teaching and learning (John B. Biggs, 2003). This discussion chapter identifies the limitations in Biggs' model (see figure 1.2) in the context of engineering Mechanics education and proposes a revised 3P model for teaching and learning in engineering Mechanics.

1.4 Scope of the Research

The research focuses on engineering Mechanics courses run in the first year of Bachelor of Engineering degree programs at four Australian universities: the University of Wollongong (UOW); the University of Tasmania (UTAS); the University of Technology, Sydney (UTS); and the Australian Maritime College at UTAS (AMC). The Mechanics courses at each of these universities were core subjects for a range of specialist disciplines such as Mechanical, Civil, Environmental, Mining, Materials, Mechatronics, and Ocean and Maritime engineering. Second year Mechanics subjects

were not considered in this study as the diversity in second your programs at these four universities would have limited the comparability of findings from each university.

The focus on first year Mechanics meant that the research also provided an insight into the many challenges students face in the first year of their study. As such, the findings of this research into first year Mechanics courses are relevant to other discipline areas, thereby adding to the potential impact of these findings.

The four institutions selected had a broadly comparable student intake in terms of demographics and academic preparation. These four institutions were included in the study as a result of pre-existing collaborative working relationships between the academics involved in teaching first year Mechanics subjects. Substantial support for educational development and strong intra-faculty staff networks also existed at these institutions.

Chapter 2
Literature review

2.1 Introduction

The problem of high failure rates in first year engineering Mechanics is widespread. In considering this problem initially, numerous studies on engineering Mechanics education had been identified. This chapter presents the outcomes of a review of the literature around Mechanics education. The literature review explored previous research on the challenges faced by students and educators in engineering education. It considered the range of different approaches to addressing student learning engineering Mechanics courses that have been reported on in engineering education discourse. In conducting this review, a division was identified between studies that investigated factors contributing to poor student performance in engineering Mechanics education, and engineering education more broadly; and studies that focused on educational interventions aimed at improving learning outcomes in engineering Mechanics courses. Hence the literature review presented here is separated into the two broad areas, and the themes emerging within these areas are then discussed.

Many of the issues identified in the literature review have also been researched extensively in other discipline areas, but an extensive exploration of this was outside the scope of this thesis. The work summarised here drew predominantly from the body of literature in engineering education and physics education. Studies relating specifically to Mechanics education were targeted, with relevant studies in similar fields of engineering education also explored.

The goal of this review was to establish what had been investigated and reported previously in the research literature in order to determine how student learning in Mechanics could be explored in a novel. The sub-question for this chapter is therefore:

How have others approached the challenge of engineering Mechanics education?

2.2 Factors contributing to poor student performance in engineering

There are numerous distinct and related contributors to poor performance in engineering Mechanics courses reported in the engineering and physics education literature. Some are considered as the focus of research, others are reported only as assumptions to

justify and evaluate developments in teaching and learning. The sections below report back on interesting studies from the engineering education literature that explored and addressed a range of potential contributors to poor learning outcomes.

2.2.1 Student motivation

The time students commit to their studies is often reported and explored as a contributing factor in low assessment scores in engineering. As a guideline, students at UoW are informed that a commitment of two hours per academic credit point (cp) is expected. A 6cp subject like ENGG152 would then warrant 12 hours of study, including contact hours (approximately 5 hours per week, averaged over a semester). Balasico and others (2007) utilised a self- reporting approach to tracking students' study hours over the course of a semester for 6 different courses, totalling 17 equivalent semesters. The students were surveyed using a compulsory spreadsheet form to track their time on task each week. Their reported study times were then compared to their academic performance in the course. The authors found no statistically significant relationship between independent study time and course grade. There was also no strong link between study hours and overall grade average across all courses of study. Balascio and others (2007) concluded that study hours alone were a poor predictor of performance, and speculated that study hours were in fact heavily influenced by the students' individual ability, rather than simply their commitment to academic achievement. In a similar study, Kember asked students to keep a diary of the time they spend on class work and related this to their perception of workload for that class. Over a sample of 266 students, Kember (2004) found only a very small, statistically significant correlation between students perception of workload and hours they put in to studying. Taking a smaller case study sample to further explore this, he found that the student with the highest perception of workload was also putting in the least amount of hours. The conclusion from this was that the recorded study hours and the perceived workload were not good indicators of likely success, which supports Balascio's claim that study hours are difficult to link to academic performance.

Kolari et al (Kolari, Savander-Ranne, & Viskari, 2008) also investigated students' use of time and their reported motivation and target grades. Using self reported measures for a first year engineering cohort, and comparing these with final course grades, Kolari et al found no correlation between time input and grade. The authors also looked into

students target grades and their achieved grades and again found no correlation. In their discussion, the authors related these findings to the teaching approaches employed across the curricula and commented that students are driven by assessments and curricula to pursue inefficient approaches to study. They argued that this could lead to students under or over investing time on certain approaches to study and that this needs to be addressed through appropriate pedagogical methods. This provided another insight into the findings of Balascio et al (2007) and Kember (2004) that while students learning needs and goals may influence how much study time has been invested, the curriculum itself may influence variations in how much time individual students need to spend on study.

Motivation for independent study and effort may also be influenced by the marks that students deem to be acceptable. This may occur irrespective of whether the effort students put in pays off as intended, and also be independent of students' interest in the subject. Therefore attempts to improve student motivation may be more effective with some students than with others. More to the point, what motivates some people can have no effect, or even an adverse effect, on others depending on their personal motivation towards study (Weiten, 2007).

Kyndt et al (2011) explored the relationship between autonomous motivation (interest in the subject etc.) and external motivation (grades, academic success etc.) on student perceptions of workload, task complexity, and lack of information. This study found that students who were motivated by a genuine interest in the subject were less likely to complain about the workload, and were also less likely than externally motivated students to report insufficient information provided by the lecturer when carrying out complex assignment tasks. In short, students motivated by genuine interest were more likely put in the necessary effort, and have a greater satisfaction with the content of the course and educational approaches employed.

A number of researchers have taken this on board and subsequently revised their course structure to motivate and interest students. Alpay et al (2010) explored the issue of external, assessment motivated approaches to learning, termed by the authors a 'marks-based culture'. The study implemented a revised assessment structure in a foundation computer science course, to take the emphasis off collecting marks during semester. This new structure was also combined with greater use of senior undergraduate students

as peer tutors. A rigorous survey of the student experience was carried out and found that while undergraduate tutors were seen by the students as more motivating than academic tutors, many students in the sample group still rated assessments as the priority for study. This outcome was supported by a survey of tutors, with both academic and student tutors in agreement that students were more concerned with marks than understanding. Importantly, the study found no significant negative impact on final marks or attendance for students in the course, despite the removal of regular assessable in-class activities.

Taking into consideration students' motivations for study and their associated interest in learning, Jowitt and Jovanovic (2007) proposed introducing Self-regulated Learning (SRL) techniques to engineering students. The authors cited a lack of interest in learning itself among students and how this could stem from students being unaware of what they want from their studies. In a small scale survey, the authors discovered only one of the 22 students who responded had a clear picture of where their studies would lead them in terms of the engineering profession. Students who appeared to have at least some background knowledge of engineering practice appeared to be more motivated for study. The authors argued that if students were more conscious of how their study was benefiting them, then their motivation to study would be improved. While results of other studies in other fields where this idea had successfully been put into practice were reported by the authors, and principles and strategies were suggested, no research into the effect of this in engineering specifically has been conducted.

Blashki et al (2007) also explored this concept of self- regulated learning as a way of motivating and engaging generation Y engineering students, they also commented that the teaching approaches used in Schools and Universities today do not adequately cater to the priorities and abilities of generation Y students, leaving them disengaged with their learning. In this study Blashki and others implemented an immersive learning environment using design studios with first year computer science students in an Australian University. The approach took into account the key attributes of generation Y students highlighted by the authors: "Flexibility, adaptability, spontaneity, and an increased disposition towards participative behaviours" (Blashki, et al., 2007, p.409).

Students were surveyed on their experience and the results of the overall assessment for the subject were compared with the previous year. The comments received from the

students in the survey demonstrated evidence of improved motivation for study as a result of the greater level of freedom provided by the immersive learning strategy. The overall results also demonstrated a shift toward Distinction and High Distinction in the distribution of grades compared to the previous year.

Similarly, Pollock (2005) introduced peer learning strategies into a basic Mechanics course in an effort to improve student motivation. The course was split into statics and dynamics with peer-learning approaches utilised in the dynamics half and not the statics half. A comparison of results for the two halves showed an apparent benefit for young males, but not females, or mature males. While this study used a small sample of students, and the results were not conclusive, the authors did comment that the peer-learning approach helped to motivate the younger male students. This group had previously tended to take a surface approach to learning in the Mechanics course at the focus of this study.

In a similar, interventional type approach, Crawford and Jones (2007) utilised a series of competitive design challenges to motivate students in a mechanical engineering design course. An evaluation of the course development employed a simple end of course survey to gage student satisfaction with the course. The results of this evaluation showed an increase in student satisfaction with the course over previous years and apparent increases in motivation, but like other studies, it did not link apparent gains in motivation with improvements in measured learning outcomes.

A study by Alpay and others (Alpay, Ahearn, Graham, & Bull, 2008) took a more fundamental approach to exploring the motivation of engineering students. Citing anecdotal observations and the changing nature of the engineering profession to a more global focus, the authors sought to understand what motivates students to take on engineering as a career in the first place, how this changes over time, and the implications for teaching. 2330 undergraduate engineering students at the Imperial College London were surveyed, as well as alumni with 1-5 years of work experience since graduation. The research found that student motivations for study shifted from the more aspirational such as making a difference to the world and inventing new things, to more practical drivers like financial security. It also found that in the early years of the degree, students were more engaged with the social/global context of engineering than in later years. The authors concluded that many students desire a more practical and

realistic focus in their studies, and that providing this could help to maintain their interest in engineering itself, rather than simply as a means to financial security.

It is apparent that there are many aspects of student motivation that may have an impact on engineering education, too many to report here. Due the multi-faceted nature of student motivation, it is apparent that this is an area that is unlikely to be addressed effectively with a single approach. Aside from Blashki et al (2007) though, few studies have linked efforts to improve student motivation to actual improvements in grades. At the very least it seems difficult to measure motivational changes and relate these to improvements in grades. As a result, student motivation is a factor that needed to be taken into account in this exploration of student learning in engineering Mechanics, but only as a factor in the overall picture.

2.2.2 Prior learning

Prior learning in topics relating to Mechanics, such as mathematics and physics, is frequently flagged as a cause of troubles for students. Dwight and Carew (2006) investigated the effect of subjects taken by students in their final year of high school on first and second year Mechanics subjects. The study discriminated between students who had or had not taken three content high school subjects, Engineering Studies, Physics, and Advanced Mathematics, and compared their scores on a week 1 entry quiz and a week 7 mastery quiz. They found that students who had taken high level mathematics in high school enjoyed a slight and consistent advantage in the first year, but by the second year that advantage had disappeared. For both Physics and Engineering Studies, the results were less clear cut, with statistically significant advantages only evident in one of the two assessments. It was interesting to note here that students who had taken engineering studies in high school, a subject with a direct content relationship with first year Mechanics were not significantly advantaged at university. The authors of this study concluded that “there is an indication that academic history is not the overriding factor in the student’s ability to learn [Mechanics]” (Dwight and Carew, 2006).

Tyson (2011) conducted a similar study looking at high school electives and their relationship to success in the early foundation courses of an engineering degree, although not Mechanics courses in particular. This US study showed inconsistent relationships between high school courses and directly related college courses. The

clearest results were between high achievement in courses at high school and college courses, including high school grade point average. The author also pointed out that students who had not developed the appropriate study skills in High school will continue to struggle through college and university (Suresh, 2006 in Tyson, 2011). This seems to suggest that students with previous academic success are more likely to continue their academic success regardless of the particular course, but this is by no means guaranteed. This is not so surprising given the extent of research in to student success in engineering and other fields, with social, financial, and many other factors also contributing (Van den Bogaard, 2012).

Research conducted by Streveler and others (2006) could offer an interesting insight on the tenuous links between prior learning and academic performance. While investigating concepts in Mechanics that students found difficult they noticed that educators involved in the study sometimes overestimated the degree to which students understood concepts. This potential mismatch between academics expectation of understanding and students' actual understanding could lead academics to overestimate the depth of students' understanding of topics that comprise the pre-requisite or assumed knowledge for a particular subject. In other words, students' actual understanding of the topics they studied in previous classes may be less than their grades indicate, and less than academics expect. Lee et al (Lee, Harrison, & Robinson, 2006) compared the Mechanics content their students had studied in high school with the expectations of academics teaching into a Mechanics course. While 11 of the 26 academics interviewed assumed no prior knowledge of Mechanics in their teaching, 15 participants overestimated the depth of content that many of their students would have studied in the A level (UK) high school courses. Thus, it is conceivable that this simple misunderstanding or lack of awareness of the actual depth of prior learning of students may be a factor in the assertion by some academics that prior knowledge is a cause of students' poor performance.

These studies, while not exhaustive, seem to suggest overall that evidence of prior learning, as measured by current assessment practices, are not consistent predictors of performance, but they may be useful indicators. Additionally, while students' prior learning and academic preparation for study is regularly cited in papers as an off-hand introductory mark, few papers actually reveal the statistics behind these assertions.

The literature described here, and other literature in the body of knowledge is relevant to the current research in terms of the broad focus on engineering Mechanics, but it does not reflect the specific content and nature of the engineering Mechanics courses at the four institutions that formed the case studies for this thesis. To determine the potential relationships between academic history and success or failure in Mechanics, a more comprehensive study using data from the four institutions was warranted. This component of the research is detailed in chapter 6.

2.2.3 Learning Styles and Preferences

A number of researchers have explored the way in which students with different learning styles and preferences and different ways of processing information have progressed academically in engineering education. Ates and Cataloglu (2007) examined the impact of student tendencies towards field-dependence or field-independence on their understanding of basic mechanical concepts and problem solving ability. Field-dependent thinkers tend to have difficulty separating an item from its context such as a single part from a mechanism. Field independent thinkers on the other hand are able to easily separate the necessary or important information from its surroundings (Witkin & Goodenough, 1981). Using the Force Concept Inventory (Hestenes, et al., 1992) as a standard for measuring student's conceptual understanding in basic Mechanics, Ates and Cataloglu found no statistically significant difference in conceptual understanding between field dependant and field independent cognitive styles. Using the Mechanics Baseline Test (Hestenes & Wells, 1992) as a measure of problem solving ability in Mechanics problems, there was a statistically significant advantage for field independent students. In their discussion the authors commented on these conflicting findings, arguing that the Force Concept Inventory does not adequately test the skills required to determine field-dependency or field independency. Since this test is widely recognised in the field, however, Ates and Cataloglu concluded that this particular cognitive style grouping may not be a useful predictor of ability in engineering Mechanics.

Several researchers have explored spatial ability and its relationship to students' performance in engineering, and engineering Mechanics in particular (Sutton & Williams, 2007; A. Williams, Sutton, & Allen, 2008). Sharp and Zachary (2004) claimed that strong spatial thinking skills were essential for the early stages of analysing

Mechanics problems. Determining an appropriate visual representation of a real world object or even a simplified example for subsequent analysis is normally the first step in any Mechanics problem. Without the appropriate spatial thinking ability, they argued, completing the first step in the process would be difficult for students. The authors proposed the Van Hiele's theory of geometry learning (Van Hiele, 1986) as a tool for improving spatial ability as it relates to engineering problems. The authors used this theory to sequence the way in which examples of Mechanics problems were introduced and explained to students in an introductory Mechanics class. While no detailed analysis of improvements in student understanding of, or performance in Mechanics was conducted, the authors did note a shift in the way the professor teaching the class viewed the learning process. There was a move away from assumptions about what problems were 'basic' to one where the professor developed a greater awareness of how students were progressing in their understanding of the material.

Sorby (2009) reported on over a decade of research into the effects of voluntary participation in a spatial visualisation course. Engineering students at the Michigan Technological University were administered the Purdue Spatial Visualisation Test: Rotation (Guay, 1977) during their orientation. Students who failed the test were given the option of attending a course to improve their performance. Improvements in performance in the PSVT:R test were consistently high as a result of the course. The Author then traced the subsequent performance in graphics related subjects (including Mechanics) and overall retention for students who failed the test and attended the course, and for those who failed and did not attend. The results showed significantly better outcomes for students who attended the course. While this approach does show a clear benefit as a result of attending the course, it is not clear whether this is a result of better spatial visualisation skills or if it is related to students motivation to take action in their learning by opting to attend the course. This research may indeed provide insights on the outcomes of students' motivations and approach to their learning but in its current state of progress, it isn't possible to discriminate between this and improvements in spatial ability.

The effects of students' learning styles have also been researched widely in engineering education (Litzinger, Lee, Wise, & Felder, 2007). Felder & Silverman (1988) published some early work on learning styles in engineering education that has since been widely

used by academics. Felder and Silverman proposed that a mismatch between students learning styles and methods of teaching could inhibit student learning. Van Zwanenberg and others (Van Zwanenberg, Wilkinson, & Anderson, 2000) took this further to investigate the ability of Felder's Index of Learning Styles (ILS) (Felder, 1996) and Honey and Mumford's Learning Styles Questionnaire (LSQ) (Honey & Mumford, 1992) to predict the academic performance of engineering students. The study found no statistically significant relationships between any factors on either of the tests and engineering students' academic performance. An important point not considered in Van Zwanenberg's et al's study is that the teaching methods that formed the basis of the students' grades were not considered in any way. Thus, it was not possible to link any for the learning style factors to the suitability of the teaching approaches as intended by the original authors of the scales (Felder, 1996).

Some researchers have sought to align their teaching approaches to students learning styles. Lowrey (2009) administered the Honey and Mumford LSQ to students in a first year electrical and electronics engineering subject. Numerous changes were made to the subject based on the results of the questionnaire to better accommodate the range of learning styles apparent in the class. These changes and the learning styles they were to cater for were communicated to students together with their LSQ results. The outcome of this study was that students reported becoming more conscious of how they were engaging with different styles of teaching and educational materials, although evidence of improvements in educational outcomes were not reported. So while the concept of learning styles is accepted by some in the field of engineering education, there is still a lack of research that demonstrates how this can be used to improve measured learning outcomes, particularly in engineering Mechanics.

Litzinger et al (2010) investigated cognition in terms of the approaches to problem solving used by students to solve typical statics problems. Litzinger et al referred to an issue that was also investigated by sharp and Zachary (2004), where students have difficulty in the early stages of solving a problem, particularly in creating an appropriate visual representation of the problem to be analysed. The authors utilised a problem solving framework together with a think aloud type study to analyse students' problem solving thought process. They were particularly interested in a finding by VanLehn and others (VanLehn, Siler, Murray, Yamauchi, & Bagget, 2003) where learning occurs

when students reach an impasse in solving the problem, and what they do when this happens. The types of Mechanics problems used were similar to those used in ENGG152 at UOW.

The results showed there was a trend towards students with stronger problem solving skills (more frequent and detailed think aloud explanations of problem solving processes) having higher scores on a Force Concept Inventory (P.S. Steif & Dantzler, 2005), spatial ability, and higher average grades in mathematics. Relating back to spatial ability, the authors also found that the participants spatial ability did not have a statistically significant correlation with performance in Mechanics problems that involved developing free body diagrams AND equilibrium equations. In terms of errors made and think aloud comments, the study also concluded that students with more developed problem solving skills spent more time analysing the problem and developing their free body diagram and made more frequent self-explanations of solution steps, and more frequent evaluations of solution quality ('is this correct because...', etc.).

In terms of cognition, there are likely to be many factors at play here. Taraban and others (2007) investigated students' response to different types of learning resources, and found evidence to suggest that students respond differently in terms of cognition levels to different types of resources (eg. text only materials vs. interactive programs). Thus, a student's performance as measured or observed in one activity may not be a true reflection of their overall or absolute ability. Their performance may be influenced by the type of assessment or learning activity, which is an important point to consider when discussing their response to particular interventions or educational approaches.

The small samples of studies here that relate to engineering education suggest that studies of this type raise many questions which are difficult to translate into learning gains. This may be particularly true for engineering Mechanics education, where few studies in this area have been done. Of the ideas discussed here, it appeared that like student motivation, investigating one aspect of cognition in isolation was not going to deliver a solution to the problem of high fail rates in engineering Mechanics. They needed to be considered as aspects of a wider spectrum of factors contributing to a poor performance in Mechanics.

2.2.4 Specific Mechanics content

The causes and themes outlined previously deal with the broader, non-specific causes of poor performance in introductory Mechanics which are commonly suggested by engineering academics. In addition to these, there are discrete causes speculated or noted in the literature that generally fall into the categories of conceptual misunderstandings, procedural errors, and knowledge gaps. As an indicator of the extent of this body of research, over 7500 literature sources containing references to these discrete causes in various science disciplines have been collected and compiled into bibliographical form by Duit (2007).

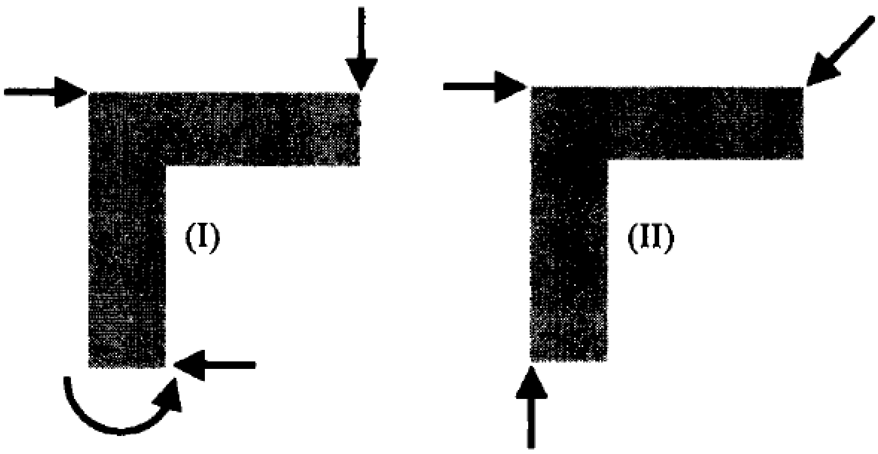
Paul Steif and collaborators have written extensively on the issue of misconceptions in Mechanics problems involving static equilibrium (Paul Steif, 2004; P.S. Steif & Dantzler, 2005; P. S. Steif, Dollár, & Dantzler, 2005; Streveler, Litzinger, Miller, & Steif, 2008). Much of this work centres round a multiple choice inventory quiz of concepts relating to an analysis of static equilibrium problems that was developed by Steif and Dantzler (2005) to test student's grasp of these concepts. This Statics Concept Inventory (SCI) organised questions into five classes:

1. Free body diagrams
2. Static equivalence of combinations of forces and couples
3. Type and direction of loads at connections
4. Limit on the friction force and its trade-off with equilibrium conditions
5. Equilibrium conditions

In this 2005 study, the quiz was completed by 105 students at Carnegie Mellon University and the responses were used to assess the reliability and validity of the test. Of particular interest here was the Criterion-related validity where the results in the quiz were compared with their performance in the statics course overall. The results showed a strong positive correlation between students' performance in the SCI and their overall performance in the subject. This would suggest that at least as far as this test and course assessment is concerned, there is a strong relationship between students' conceptual understanding in Mechanics and their overall ability to solve Mechanics problems.

In earlier work, Steif (2004) proposed that the apparent simplicity of statics can cause instructors to underemphasise the less obvious aspects of the equilibrium principle. Newcomer and Steif used the SCI to investigate students understanding of equilibrium in more depth through their reasoning behind responses to test items (Newcomer & Steif, 2008). Focussing in on one particular test question with a consistently low correct response rate (see Figure 2.1), the authors asked participants to include a written explanation supporting their chosen response in a process similar to the think-aloud method used by Litzinger et al (2010) (see 2.2.3). In addition, students were asked to explain in writing why each possible response was correct or incorrect. Selecting the correct answer to this question (b) required students to develop both force equilibrium equations and moment equilibrium equations to realise that neither case could be in equilibrium.

The forces and couple in the two cases shown act at the points indicated. All magnitudes are greater than zero, and the forces and couple act in the directions and senses shown.



Assuming the magnitudes of the forces and couple have the right values, could these bodies be in equilibrium?

(a) I could be in equilibrium; II could be in equilibrium
(b) I could never be in equilibrium; II could never be in equilibrium
(c) I could be in equilibrium; II could never be in equilibrium
(d) I could never be in equilibrium; II could be in equilibrium
(e) Cannot say without more information

Figure 2.1, SCI question taken from Newcomer and Steif (2008, p.482)

In their results and discussion, Newcomer and Steif unfortunately did not go far beyond the consideration of this particular question. This paper is typical of many studies focussing on particular misconceptions, reporting on student's misconceptions, and how

these may be addressed, but not relating back to the wider picture of Mechanics instruction where failure rates remain high.

Steif and Dantzler were not the first to investigate conceptual understanding in Mechanics using this type of measure. A widely used tool in this area developed by Hestenes, Wells and Swachamer in the early 1990's is the Force Concept Inventory (FCI) (Hestenes, et al., 1992). Based on earlier work by Halloun and Hestenes (Halloun & Hestenes, 1985a, 1985b), Hestenes et al argued that student understanding of Mechanics is informed by years of personal experience in the physical world. This experience can lead to an understanding about Mechanics concepts that is at odds with reality, and that instruction in Mechanics must take this into account. From this premise, they developed an inventory of concepts in basic Newtonian physics (Mechanics) to assess students' conceptual understanding before they begin to study Mechanics. As in the Steif and Dantzler SCI, the questions in the FCI were multiple choice with distracters derived from commonly observed misconceptions held by students. In a pre-post implementation of the FCI in several universities and high schools, the authors only identified marginal gains as a result of instruction in basic physics. Interestingly, scores in the pre and post testing were similar between university cohorts and high school classes. In their conclusion, the authors discussed the problem of overcoming misconceptions identified by the test, and how simply showing students their result or attempting to teach directly to the test was unlikely to be effective. The authors also warned against dealing with specific misconceptions in isolation because students' understanding of them is often interrelated.

This brings us to a study by Espinoza (2004). Espinosa explored the effect of changing the order in which the concepts of force and momentum were introduced to high school students. One group of students was given instruction introducing force before momentum while the other was introduced to these concepts in the reverse order. A post- test indicated that most of the students in both groups had a sound understanding of momentum in a projectile motion question while a much greater percentage of students in the second group exhibited a sound or progressive understanding of force. The Author argued that these two concepts were linked and that introducing momentum first was more appropriate for addressing students' preconceptions. This would seem to support the notion of interrelated concepts needing appropriate instruction.

Looking at the sheer volume of studies of misconceptions in Science, Technology, Engineering and Mathematics (STEM) courses, Flores Camacho et al (2004) undertook an extensive project to convert an early version of the Duit bibliography and additional information into a searchable database. This database offered some interesting insights on the issue of misconceptions. A search on Mechanics related topics in the database returned over 70 documented misconceptions. In their overall analysis of the literature Flores Camacho (2004) suggested that to rectify misconceptions and improve educational outcomes, many educators only address a handful of misconceptions. Like Hestenes and others, Flores Camacho et al (2004) also noted that addressing misconceptions in isolation may be ineffective because they are often interlinked. This limited approach could explain some of the poor results observed from targeted interventions in the teaching and learning of introductory Mechanics.

2.3 Attempts to improve educational outcomes in engineering Mechanics

This section describes previous studies and initiatives that set out to improve grades and student learning specifically in engineering Mechanics courses. There are many documented attempts at doing this, some successful, others less so. It was evident from the literature that these studies tended to focus on a particular type of intervention or a particular aspect of engineering Mechanics. This has informed the break-up of the following sections into types of educational interventions.

2.3.1 Computer based and online learning

Computer based learning modules are a popular approach to improving learning in Mechanics, and have taken many forms (Hadgraft, 2007, 2010). Steif and Naples (2003) early efforts in developing online courseware to improve learning outcomes for Mechanics of materials students were some of the more successful. The modules were developed on the premise that “By solving a number of similar, but non-identical problems, students can more easily elucidate the underlying fundamentals, rather than memorize an independent method for solving each type of problem” (Paul Steif & Naples, 2003, p. 239).

The modules were also developed to deliver feedback in the form of hints towards the correct answer. The courseware covered some of the more advanced topics in the Mechanics of materials, but included some of the key topics targeted in this thesis, such as shear force and bending moment diagrams. The impact of the modules was assessed

using a sample of 318 students over two years, at three different institutions. These students were split into two groups, one group using the modules (experimental group) in class and the other using a standard textbook style tutorial problem set (control group). Class test outcomes between the two groups were then compared. For the module covering shear force and bending moment diagrams, the mean grades for the experimental group were higher for all six module objectives. These differences were small and only three were statistically significant. For another module dealing with internal forces and moments, statistically significant mean differences were evident for all six module objectives, with the experimental group again scoring higher. For the other three modules described in this study, there were no statistically significant mean differences between users and non-users. This is an intriguing outcome, as only 2 of the 5 modules made a statistically significant difference to the students test performance.

In a similar but less rigorous study, Philpot and others (2005) tested interactive courseware designed to improve student understanding of shear force (V) and bending moment (M) diagrams. This courseware was slightly different to the Steif and Naples one in that individual questions in the modules were more akin to traditional textbook questions, but with an added dimension of interactivity and guidance provided by the software. The software was trialled with a group of 97 students, with a further 133 taught in a traditional manner to form the control group. An exam was conducted for all students following the V/M component of the course and the students' shear force and bending moment diagrams were rated on a three point scale on the basis of perfect diagram, minor errors, or major errors. They reported a statistically significant improvement in exam marks for V/M questions among students who had used the software. 97% of this group constructed a perfect V diagram compared with 77% for the control group. The difference was similar for M diagrams, but this time with only 60% of the user group constructed a perfect diagram. Upon review of the final examination marks, these differences were maintained.

Both of these examples demonstrate the possible advantages of interactive, computer based resources for targeted improvements in learning. Interestingly, Steif and Naples (2003) noted that these resources did not necessarily work for everyone and should be considered an enhancement to face-to-face teaching, rather than replacing it. They noted that the approach was unlikely to be as successful when used in isolation.

Both these examples relied not only on a different way of supporting students in their solution of typical textbook problems, but also on encouraging them to practice solving problem examples. In the student feedback for both of these approaches, their common remarks around the online courseware were that they encouraged or even forced repetition of problems. If repetition is the key to succeeding in Mechanics for some students, then these online, interactive modules may be a useful way forward. However, they may not be the only way forward. A different approach to face-to-face instruction that also encourages more engagement with the course material may be just as effective.

2.3.2 Teaching and improvements in the curriculum

Approaches that promote active learning and engagement of students' interest are another common approach evident in the literature. Some, such as Crawford and Jones (2007), aimed to spark interest and encourage enthusiasm for the subject (see 2.2.1), a goal for which the student feedback indicates they are successful, but this was not linked definitively to an improvement in student success. Some aimed to encourage student interaction with their peers so that they may learn from each other, but again, linking observed improvements in engagement to improvements in learning outcomes is inconsistent at best (Pollock, 2005). Others try to make the learning experience more tangible, introducing concepts with the aid of simple hands on tools (Ji & Bell, 2008, 2012; Karim, 2010; Linsey, et al., 2007) or unaided model building (Dwight, McCarthy, Carew, & Ferry, 2006). Ji and Bell [54-55](2008, 2012) developed a series of simple, hands-on resources made from everyday items to demonstrate the fundamental principles of structural Mechanics. The text developed around these resources has been adopted at several sites in the UK and in China, a demonstration of the popularity and acceptance of this approach. However, no evaluation has been published linking this approach to improvements in learning outcomes.

Linsey et al (2007) did attempt to evaluate the effect of using simple demonstrations called Active Learning Products (ALPs) (Jensen & Wood, 2012) by providing access to an online resource called VisMOM (Visual Mechanics of Materials) in a statics and Mechanics of solids course though a survey, focus group, concept inventory, and the use of a pre and post- test relating to the demonstrations. The quantitative results from the pre and post testing using a control group that were not shown the ALPs suggested there was an advantage for those who had access to them. The way in which the data and the

results were presented, however, made it difficult to judge the validity of this finding. Looking at the outcomes of the quantitative survey measure and qualitative focus group, students were generally positive towards the ALPs, but many were still unsure whether this would help them with quiz or exam questions. When this was probed during the focus groups, students reported that the ALPs helped them with their conceptual understanding, but not with their analytical skills. This is another interesting insight on 2.2.4, where many of the interventions and research approaches focus on conceptual understanding but not on a student’s ability to convert this to solving problems.

The engineering education literature also includes examples of more traditional instructional approaches that have been refined from years of experience. Karim (Karim, 2010), like Linsey et al and Ji and Bell, included practical demonstrations in their teaching to improve student understanding. He reports on his use of models, parallel presentations of real world scenarios and idealised diagrams, and simple demonstrations. The method of presenting these educational practices typifies common conversations with engineering academics, where practices are explained but the research that demonstrates the effectiveness of such approaches is not undertaken. Authors like Kessissoglou and Prusty (2009) took this approach to a more advanced level when they reported on the success of attempts to blend online tutorials called Flying Fish (Scott & Stone, 1998) and individual and group project with well planned traditional lectures and tutorials. Through this combination, the failure rate was reduced from a five year average of 33.4% (maximum rate 41%, minimum rate 23%) down to 19% overall. An overall improvement in rates of higher grades of credit, distinction, and high distinction was also reported. While this improvement is commendable, the 19% fail rate is still high compared to other courses in the first year at the participating institutions, and it is not unusual for first year Mechanics.

Papadopoulos and others (Papadopoulos, Bostwick, & Dressel, 2007) implemented an alternative method of teaching engineering Mechanics problem solving that emphasised a) solving problems using multiple methods, b) writing up all equations in a standard matrix form, and c) ensuring that all assumptions are carefully addressed. This approach was implemented in an early year Mechanics subject. The authors remarked that this approach was not structured around a rigorous method to evaluate its success, as is common in studies of this type, but they did attempt to measure differences in student

performance in follow on subjects as a result of whether they had experienced this approach or not. The approach taken for this was statistically questionable but it did suggest some advantage for students taught by this ‘holistic problem-solving’ approach.

These are some examples of the types of approaches implemented to improve student learning in Mechanics, many more are not documented in the literature, and although these approaches often receive positive feedback from students and even small improvements in grade averages, they rarely result in significant improvements in grades. As seen here, the more rigorous research into student learning benefits has focussed around online learning, where clearer demonstrations of grade improvements have been published (see 2.3.1).

2.4 A holistic picture of teaching and learning

This review of the literature relating to engineering Mechanics education has explored other researchers’ and practitioners insights into why so many students struggle with engineering Mechanics. It is clear there have been many studies into the various factors that may contribute to high fail rates, but there are also many different approaches that engineering educators have taken to try to improve learning in Mechanics. Improvements in pass rates in Mechanics subjects *beyond* what has occasionally been achieved at the four institutions at the focus of the current study (see 3.1.1) has not been reported in the literature explored thus far. Failure rates in the order of 15-20% are the best that has been reported in the literature reviewed here, and most sources do not report these overall rates at all.

Whilst the literature identified many issues they tended to have been studied in isolation, whereas the studies that focussed on Mechanics tended to focus on specific issues in Mechanics, whether they were misconceptions, academic history, teaching methods and interventions etc., and then reported on the outcomes of interventions addressing those specific areas. Given the fragmented success reported for these focussed approaches, more needs to be understood about how Mechanics education functions in a holistic sense.

There are a number of models in the higher education literature that proposed more complete, or holistic representations of the teaching and learning process. There are also models of education that emphasised the need to consider various aspects of learning in

the design of instruction. One popular model presented by Kolb (1984, p.21), drawn from the work of Lewin, explains learning as an experiential process. In this process Kolb argues that learning involves an experience, observations and reflections on the experience, the formation of an understanding of the experience, and finally, the application of this understanding to new scenarios (see figure 2.2). It could be argued that some of the studies presented above are aligned with this model in terms of the way learning activities are designed to help students engage with Mechanics textbook problems. However, the wide range of factors impacting on student learning identified in this literature review suggested that students 'concrete experience' goes well beyond concepts introduced in class or in learning resources. Concrete experiences may also involve interactions with educators, other students, and the outcomes of assessments.

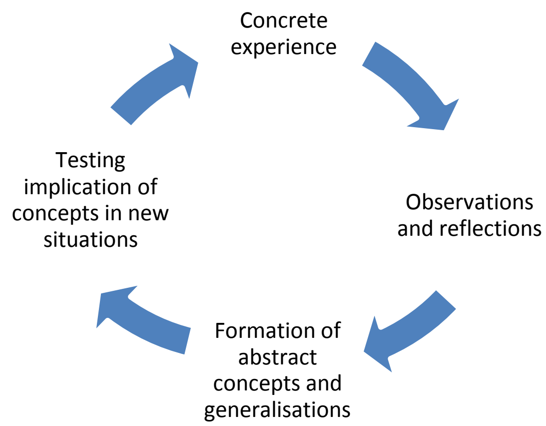


Figure 2.2 Kolb's experiential learning cycle

Another interesting model that can be used to better understand the way students engage with learning and in the design of curricula is the Cynefin Domains of Knowledge (Kurtz & Snowden, 2003). This model can be used to consider the forces found regularly in classrooms, so it is useful for designing a learning experience as opposed to discrete learning activities (Goldfinch, Leigh, Gardner, Dawes, & McCarthy, 2012). It uses the concept of cause and effect relationships to explore five different conditions that may be found at different times in education, expressed in the model as domains of knowledge (see figure 2.3). These domains help to understand how students may respond to learning experiences where traditional education, as often seen in Mechanics education, mainly focuses on the 'ordered' domains on the right. The 'visible order' is the known cause and effect relationships such as the layout of a lecture theatre and the subsequent function of a traditional lecture. The 'hidden order' describes the causes and

effects that can be identified and repeated. These are discovered under the guidance of a teacher and include the types of Mechanics problems used in the major engineering Mechanics textbooks.

The 'un-ordered' domains on the left describe more complex design or management related challenges, where interaction between variables can be chaotic and complex. The shaded area in the middle of figure one is of key importance to the design of learning activities. This fifth region is referred to by Kurtz and Snowden as 'Disorder'. It is often the starting point when considering a problem where the relationship between cause and effect is not known. If not managed effectively in the learning environment, students situated in this region of the model during a learning experience can pursue inappropriate or ineffective strategies for solving the problem, or in the case of the learning experience as a whole, they may pursue ineffective approaches to study.

The Cynefin domains model is a novel and intriguing one because it was difficult to apply to the issues around the engineering Mechanics teaching and learning identified here. Much of the research in Mechanics education revolves around students' understanding of 'hidden order' problems, where the solution is knowable through a defined process.

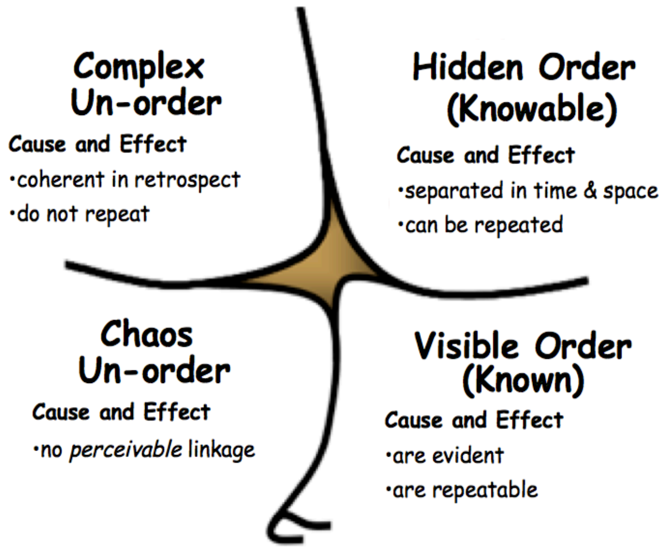


Figure 2.3 The Cynefin Domains of Knowledge (Kurtz & Snowden, 2003)

A more detailed model of teaching and learning has been developed and studied by John Biggs and collaborators over several decades (J. Biggs, 1999; John B. Biggs, 2003; J.B. Biggs & Telfer, 1987; Li-Fang, 2000). This model presents the teaching and learning

process as a three stage system where factors present before (Presage), during (Process), and after (Product) a learning activity or course interact.

The 3P model has been presented in various forms by its original Author(s). Early versions of the 3P model presented the learning and teaching process as a linear process, with all factors contributing to the final outcomes of learning. The version of the 3P model in figure 2.4 indicates a strong focus on students, with minimal consideration of teaching and assessment approaches. A later version, Figure 2.5, takes greater account of teaching and its impact on how students approach a given learning task.

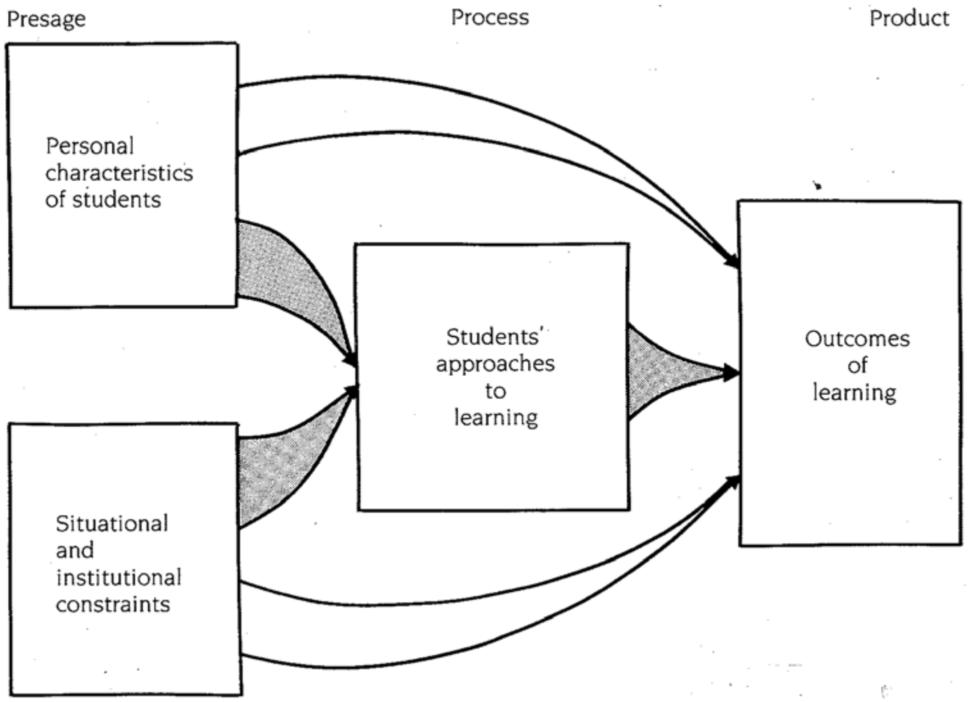


Figure 2.4 3P model (Biggs & Telfer, 1987, p. 153)

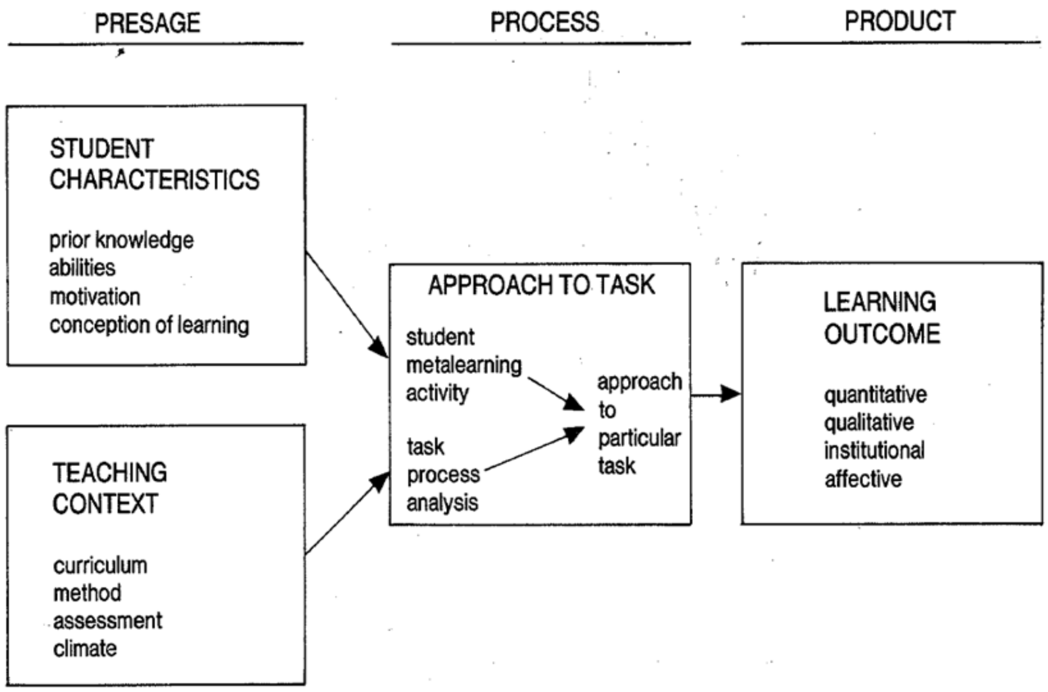


Figure 2.5 3P model (Biggs, 1991, p. 16)

Other authors in this field have also adapted and expanded the 3P model. Prosser et al (Prosser & Trigwell, 1999; Prosser, Trigwell, Hazel, & Gallagher, 1994) presented an adaptation of the model based on an analysis of the student experience of teaching and learning in higher education (see figure 2.6). This model built upon Biggs' 1991 version of the 3P model (fig.2.5), placing a greater emphasis on how students' perception of the learning experience relates to how they approach learning activities and assessments.

A later version of the 3P model published by Biggs in 1999 suggests more complex interactions between learner, teacher, and context (J. Biggs, 1999). This model (see fig. 2.7) incorporated an approximation of the interrelated nature of the presage-process-product and some description around this. The 1999 model appears more focused on the role of the teacher in the learning process and presage than the earlier models. This is seen in the shift from descriptions of 'students' approaches to learning' and 'approach to task' to 'learning focused activities' as the process in the model. However, like earlier models, it also describes a predominantly linear model of learning as depicted by bold arrows.

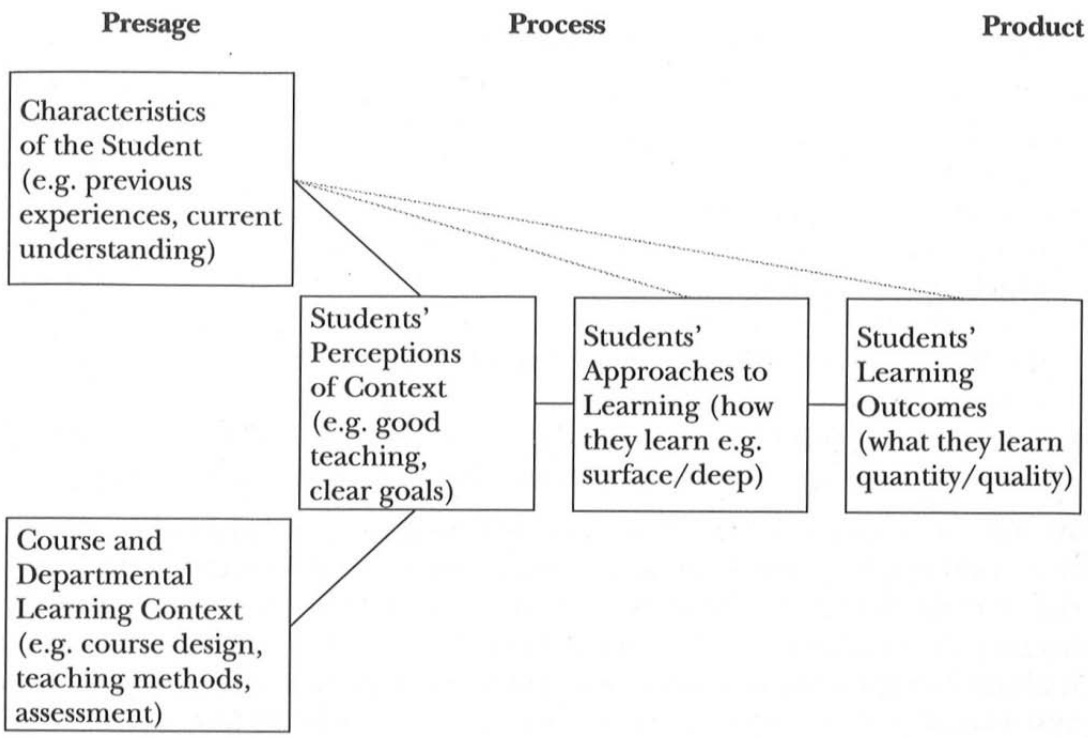


Figure 2.6 3P model (Prosser & Trigwell, 1999, p. 12)

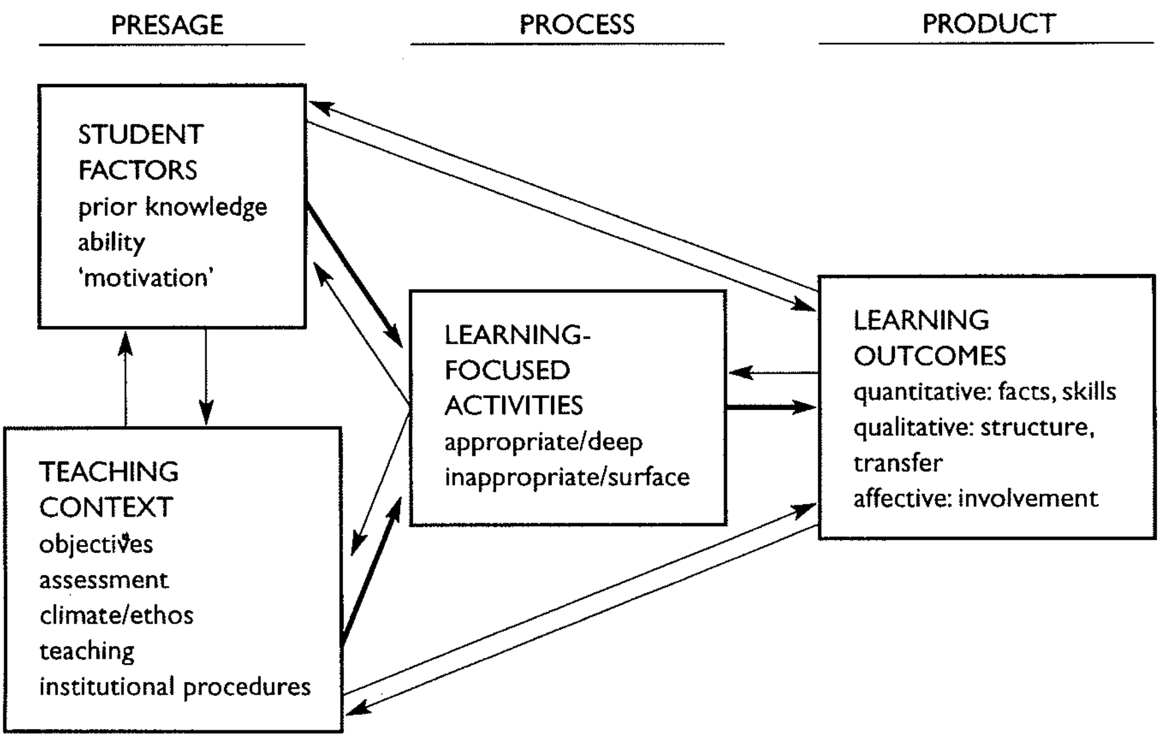


Figure 2.7 3P model (Biggs, 1999, p. 18)

Unlike the Kolb and Cynefin models presented above, the previous work in engineering Mechanics identified in the literature could be clearly mapped to the 3P model. Much of the work in the area of engineering Mechanics details how learning activities were developed and implemented (Process), with a brief reference to the teaching context. Much of the work in this area details how the learning activities were developed and implemented (Process) with reference to the teaching context, and normally driven by the need to take the Student factors (presage) into greater consideration. In terms of learning focused activities, many approaches presented in the literature utilised alternative and highly structured approaches to learning design (Linsey et al., 2007; Papadopoulos, Bostwick, & Dressel, 2007; Philpot, Hall, Hubing, & Campbell, 2005; P. Steif & Dollár, 2009; Paul Steif & Naples, 2003). Of these studies, none reported substantial improvements in measured learning outcomes overall using these approaches.

Some studies also refer to learning outcomes (Product). In some of the more robust studies, such as those by Steif and Litzinger (Litzinger, et al., 2010), standard tests such as the Force Concept Inventory (Hestenes, et al., 1992) and Statics Concept Inventory (P.S. Steif & Dantzler, 2005) were incorporated and administered pre and post intervention to measure learning gains. Others take a more qualitative approach by evaluating student perception of learning improvements and overall student satisfaction with the course or resource design (e.g. Crawford & Jones, 2007). Consideration of the presage in these studies was limited to an overview of the factors that are the motivation for educational development. These include an institutional context, assumptions about students' preparedness for Mechanics, and student engagement, or reference to issues highlighted in other studies carried out in different contexts.

2.5 Chapter Summary

This literature review has shown that previous studies in engineering Mechanics teaching and learning have focused on particular issues, topics and teaching approaches. While these studies contribute to understanding of Mechanics education, they have been conducted in isolation from a holistic teaching and learning model such as the Biggs 3P model. Although the studies here consider elements of the 3P model, Biggs emphasised the importance of considering learning and teaching in a holistic way. Presage, process, and product all need to be considered within the same context (or study). The 3P model

has not previously been used to research student learning in engineering Mechanics, and while much of the previous work can be aligned to various elements of the 3P model, the model has not yet been considered within a single study in engineering Mechanics. Therefore, the 3P model was identified as an appropriate theoretical framework for reflecting on data collected teaching and learning in Engineering Mechanics.

Chapter 3

Educational context of the research – Introductory Mechanics education at UOW, UTAS, UTS and AMC@UTAS

3.1 Introduction

To explore the multitude of factors at play in the context of first year engineering Mechanics learning and teaching, four courses were identified as typical cases for research. As outlined in the previous chapter, this research needed to develop a more holistic understanding of Mechanics education. This chapter details the context in which the research was conducted, primarily focusing on the content and structure of the four courses that form the data source for this thesis. The data used in this thesis was drawn from four Australian Universities: the University of Wollongong (the primary source of data); the University of Tasmania; the Australian Maritime College (amalgamated with UTAS after the commencement of this research); and the University of Technology, Sydney. The chapter provides an overview of the four courses as a reference point for the remainder of the thesis.

Establishing the educational context in this chapter drew from information available in the course outlines for each of these universities and the final examination papers for each course. An analysis of these final examination papers was also used as a starting point for establishing a working relationship with the contacts at each of these institutions, as well as to understand more about the content in these first year engineering Mechanics subjects. These papers were reviewed in brief by one full time teaching/research academic from each institution that had current or past involvement with teaching the Mechanics course. The exercise sought to understand the content taught and assessed in each school, the nature of the work expected of students, and the different levels of difficulty, or academic standards of each course.

In comparing these four courses and detailing the educational context, this chapter addresses the sub-question:

What are students expected to learn in first year engineering Mechanics?

3.1.1 Educational context – A broad description of each course

Below is a brief summary of the structure, assessment, and learning outcomes of each course, extracted from the subject outlines. The sub-sections following provide a further summary of the week-to-week topic coverage and the teaching and assessment practices used in each course. The full subject outlines are included in appendix A.

UOW – ENGG152 Engineering Mechanics (2007-2008)

This course was structured around a 13 week semester, with one 2 hour lecture and one 2 hour tutorial each week, plus three 2 hour laboratory sessions. Assessment for the years 2007 and 2008 was made up of six laboratory reports (10% total, evenly weighted), six tutorial quizzes (30% total, evenly weighted), and a final exam making up 60% of the total assessment for the course. The learning outcomes for this course in 2007 were:

- Resolve components of forces and determine resultants of force systems.
- Determine the reactions, resultants, and equilibrium conditions for rigid body systems.
- Understand how internal forces are transmitted in beams and trusses and calculate the shear forces, bending moments, and axial forces in truss elements.
- Determine the main cross sectional properties of shapes, namely, centroid, and the first and second moments of area and moment of inertia for solids. Students will gain an understanding of the applications of these concepts.
- Understand dynamics, i.e. the motion of bodies without reference to the forces that cause motion.
- Understand kinetics, which deals with the relations of unbalanced forces and resulting changes in motion.
- Comprehend the three basic principal methods of analysis: force-mass-acceleration, work-energy, and impulse-momentum.
- Apply to simple practical problems found in contemporary engineering situations.

Table 3.1 shows the history of overall fail rates in this course from 2002-2010. This data showed that the problem of high fail rates in this subject have been persistent, and as high as 42% of the class. This first year Mechanics subject is also a pre-requisite for enrolment in the second year Mechanics subject, ENGG251, Mechanics of Solids. The

long term fail rates for this subject and a subsequent 3rd year civil engineering structures subject are also shown in table 3.1. This indicates that the issue of high fail rates in Mechanics is not unique to ENGG152.

Table 3.1 Percentage of UOW engineering students failing Mechanics subjects

Subject	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	**2010**
1st yr Mechanics	24%	28%	36%	42%	31%	25%	32%	23%	25%
2nd yr Mechanics	34%	50%	44%	19%	20%				
3rd yr Mechanics (Civil)	29%	46%	43%	59%	45%				

AMC – KNT112 Engineering Mechanics (2007)

This subject was also structured around a 13 week semester with a three hour lecture each week and a two hour tutorial, plus two practical/laboratory classes. The assessment structure comprised of four quizzes (2.5% each), and in-class test (15%), one individual submission assignment (15%) and a final exam that, like UOW, comprised 60% of total assessment. The learning outcomes stated for this course were:

- Resolve a system of forces and moments into a central force and moment.
- Calculate the acceleration of an object under the influence of a system of forces and moments.
- Construct angular velocity and acceleration diagrams for simple mechanisms.
- Calculate the moment of inertia of simple geometric bodies.
- Calculate velocities and maximum forces resulting from an in-line impact.
- Find, both analytically and graphically, the linear and angular accelerations of members moving in general plane motion.
- Select simple motion transmission systems.
- Explain and calculate stress and strain for one dimensional systems.
- Explain simple harmonic motion and calculate the basic properties.

Table 3.2 below, presents the failure rate for KNT112 and a second year Mechanics subject from 2002-2006. Apart from one unexplained outlier of 8% for the 2nd year subject in 2005, the fail rates for Mechanics at AMC also tended to remain at or above 20% of the class. The reasons for the 8% fail rate outlier were discussed with the academics from AMC involved in this research, but unfortunately, detailed information on this was not available for inclusion in this work.

Table 3.2 Percentage of AMC engineering students failing Mechanics subjects

Subject	*2002*	*2003*	*2004*	*2005*	**2006**
1st yr Mechanics	44%	31%	19%	25%	23%
2n yr Mechanics	15%	31%	24%	8%	32%

UTS – 48321 Statics (2006)

This statics only subject was structured around a 14 week semester. It was assessed intensively in comparison to other subjects in this group with individual assessments made up of a 5% end of subject report, 6 in-class quizzes (25% total) and a final exam worth 60%. There were also several regular assignments comprised of simple problem sets which students had the option of completing as a group (10% total). Specific learning outcomes were:

- Understanding of the concept of equilibrium and its application in structural analysis
- Ability to simplify and clarify problems using free body diagrams
- Ability to analyse simple structures such as beams, trusses, and pin-jointed frames subject to various loadings and support conditions
- Ability to determine internal actions in statically determinate structures and draw internal action diagrams
- Appreciation of the design process, safety factors and the issues involved in design, taking into account the constraints and expectations needed to meet often conflicting design requirements
- Skill in designing axially-loaded, tensile structural members.

Table 3.3 shows the fail rates for this course over a four year period. The average fail rate is the highest of the data available for the four courses here.

Table 3.3 Percentage of UTS engineering students failing first year Mechanics (Statics 48321)

	2003	***2004***	***2005***	**2006**
Total number of students enrolled	115	110	168	245
Percentage failure	50%	36%	59%	42%

UTAS – KNE112 Engineering Mechanics

The UTAS KNE112 subject is again structured around the typical 13 week teaching semester. Contact hours are very similar to the AMC KNT112 course, with three one hour lectures each week and one 2 hour tutorial. There were no lab classes for this subject, but one field trip was included. Assessment involve three in session quizzes worth 6% each (18% total) and an end of semester exam worth 70%. The remaining 12% was allocated to tutorial attendance and participation over the semester, with no formal assessment task.

The learning outcomes for this subject were stated in the course outline simply as the development of skills in and understanding of:

- Vector arithmetic
- Statics of particles
- Rigid bodies: Equivalent systems of forces
- Equilibrium of rigid bodies, calculation of reactions
- Distributed forces: Centres of gravity and centroids
- Kinematics of particles
- Kinetics of particles: Newton’s second law
- Kinetics of particles: Energy and momentum methods
- Friction

Details of year-to-year fail rates in this course were not formally offered for publication in this research. However, a ‘ball park’ figure of around 25% each year was given. This is a similar figure to the averages for the other three courses.

Each of the four Mechanics subjects here follows the traditional lecture/tutorial/lab format, underpinned by one or more of the texts outlined in 2.3.3. Assessment for all four subjects was predominantly through summative quizzes, though AMC and UTS did also assign 15% of the total assessment to different types of assignments. Overall, all four courses could be said to be traditional in their delivery and assessment.

The teaching and assessment strategies used were explored further in the next chapter, where academics and students from UOW were interviewed for their views on the current course structures.

3.1.2 Mechanics topic coverage

Table 3.4 shows the week-to-week content covered in each course as described in their respective course outlines. The table shows that UOW and UTAS are quite similar in their statics/dynamics focus, aside from the exclusion of truss analysis at UTAS. AMC has a much greater focus on Dynamics, with only a basic coverage of statics concepts in comparison to UOW and UTAS. The UTS course is focused only on statics content, and as can be seen in the table, this course takes a much deeper approach to this content that the Statics component of UOW and UTAS.

Table 3.4 Weekly lecture content for each course

Week	*UOW*	*AMC*	*UTS*	*UTAS*
1	Introduction to Dynamics, Rectilinear Kinematics, Graphical Methods	Forces and Moments	Introduction to Mechanics (Statics). Structures and structural members. Vector addition and subtraction. Resultants and components of a force.	Introduction; Statics of particles : forces as vectors, equilibrium of a particle
2	Introduction to Statics, Revision of Equilibrium, co-planar force systems, 3D force systems	Forces and Moments Velocity and Acceleration	Free-body diagrams 2 D equilibrium 2 D Rigid Bodies: Principle of Transmissibility Moment of a force, Varignon's theorem, force/couple systems	Introduction; Statics of particles : forces as vectors, equilibrium of a particle
3	Curvilinear Motion, Rectangular Components, Projectile Motion, Normal & Tangential Components, Cylindrical/Polar Coordinates	Velocity and Acceleration	Load paths Idealisation of supports and connections for 2D bodies; Free body diagrams; Equilibrium of 2D bodies; Statically indeterminate systems	Rigid bodies: moments, couples and equivalent systems of forces
4	Force system	Friction Forces	Analysis of pin-jointed	Rigid bodies:

	resultants, Moments and rotational equilibrium, revision of free body diagrams	Equations of Motion, Energy and Power	frames Types of beams. Distributed loads	moments, couples and equivalent systems of forces
5	Relative/Dependent Motion, Newton's Laws, Kinetics of Particles, Equations of Motion, Friction	Equations of Motion, Energy and Power	Pin-jointed trusses –simple and compound. Method of joints. Method of sections	Rigid bodies: equilibrium in two and three dimensions
6	Equilibrium in 3 dimensions Trusses method of joints	Stress and Strain	Simple stress and strain; Young's modulus; Hooke's Law; Axial deflection, Poisson's ratio; Factor of safety, ultimate and allowable stress. Limit State Design Philosophy.	Rigid bodies: equilibrium in two and three dimensions
7	Work and Energy, Conservation of Energy, Kinetic and Potential Energy	Stress and Strain	Euler buckling. Introduction to Mechanics of solids. Properties of areas – centroid, first moment, second moment of area. Parallel axis theorem. Composite areas	Distributed forces : centroids and first moments; Friction
8	Trusses method of sections Internal forces, shear force, bending moment	Thermal Expansion and Stresses	Introduction to internal actions	Forces in beams, support types, bending moment and shear force diagrams
9	Linear Impulse and Momentum, Direct Central Impacts	Kinematics of Mechanisms	No lectures	Particle Kinematics : rectilinear motion, uniformly accelerated motion, curvilinear motion
10	Diagrams for shear force and bending	Kinematics of Mechanisms	Diagrams of internal actions in straight beams – effects of external concentrated and distributed loads, applied moments and support conditions	Particle Kinematics : rectilinear motion, uniformly accelerated motion, curvilinear motion
11	Oblique Central Impact, Angular Momentum and Impulse,	Balancing Rotating Masses	Internal action diagrams for straight beams; Internal action diagrams for simple frames; Internal action diagrams for bent beams.	Particle Kinetics : equations of motion, angular momentum, work, energy and power, impulse and momentum
12	Properties of cross sections and volumes, centre of area and centre of gravity, First and second moments	Simple Harmonic Motion	Equations of shear and bending moment Drawing shear force and bending moment diagrams	Particle Kinetics : equations of motion, angular momentum, work, energy and power,

	of area, parallel axis theorem, moment of inertia. Product of inertia			impulse and momentum
13	Review of Statics and Dynamics	Revision	Revision	Revision
14	Finished	Finished	Revision	Finished

Overall the topics covered by these four subjects represented a good range of introductory Mechanics concepts. The fact that the four subjects differed in content but all had consistently high fail rates indicated that these differences would not necessarily influence student performance.

3.2 Method – Benchmarking of final examinations

From 3.1.1, it can be seen that the final examination is the most substantial component of assessment in each of the four courses. This appears to be a common theme among first year engineering Mechanics courses based on the uniformity of this sample of courses. Forming 60-70% of the total assessment for each course, the final examinations are a significant determining factor in students' success in Mechanics and the subsequent rate of failure. In addition to this assessment weighting, UTS and UOW also required students to achieve a minimum exam mark of 50% and 40% respectively to pass the course overall. An understanding of what is included in the exam was required to determine the expectations placed on students in these courses. A simple comparison of the content, format, and levels of difficulty of the final examination papers from each university was conducted to:

1. establish what variations may exist in Mechanics assessment between the four schools;

2. identify similarities between the exam papers which may enable student responses to be compared;

3. explore academics' understanding of each question with respect to the level of difficulty and what is being assessed;

4. identify any significant differences in terminology, question wording, and types of problems used in each exam;

The practice of conducting an external peer review of final examination papers is common in other countries such as the UK (QAAHC, 2004), but it is not widespread in Australia. So for the academics involved, this comparison exercise also provided a useful opportunity to see how exam papers are structured elsewhere.

The process for comparing the four papers was discussed and agreed upon by the group of four academics participating. It was agreed that the comparison would involve:

1. Identifying the key concepts in each question;
2. Commenting in the procedures required to solve each question;
3. Rating the level of difficulty of each question on a simple three point scale: 1 – Straight forward; 2 – Moderate; 3 – Challenging.

Figure 3.1 is the roadmap developed in consultation with the four academics to guide the exam paper comparison process. The roadmap also included details of research to be conducted following the comparison to contextualise the work and provide clarity on its direction. Stages three and four are early plans for the detailed analysis of the examination paper and transcript that is covered in Chapter 4.

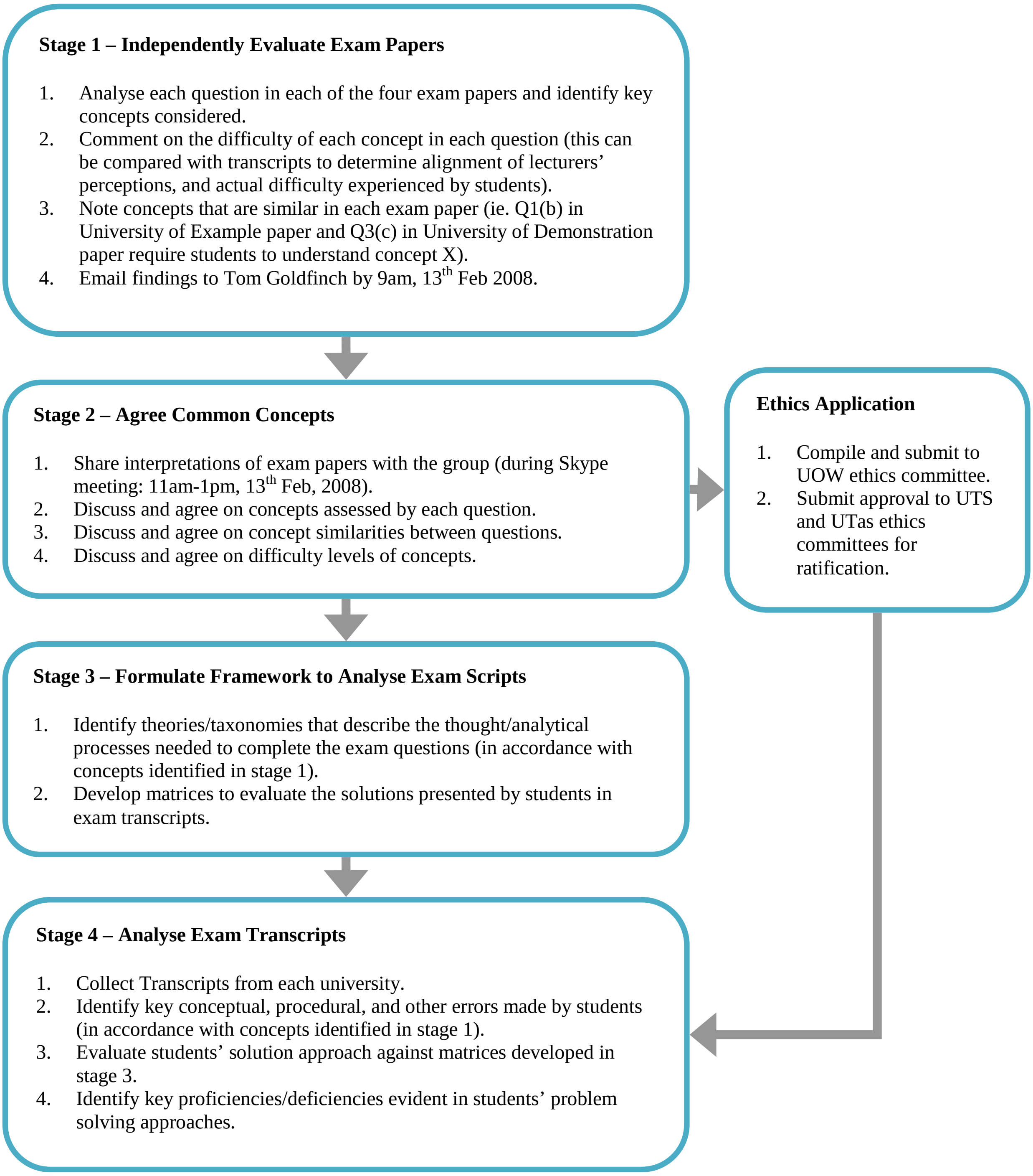


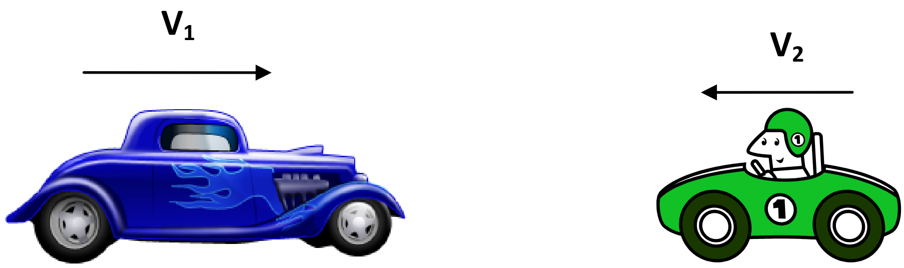
Figure 3.1 Exam Paper analysis roadmap

Each of the four academics reviewed each paper, including their own. The results of this were sent to the author, and distributed to the other academics for discussion during a teleconference. Some issues were discussed during this teleconference, but it quickly became apparent that the amount of data drawn from the comparison was too substantial to discuss in detail in this format, so the results of the comparison were collated and

distributed to the four academics for comment via email. The outcomes of this review discussion process are discussed in terms of the academics experience in section 3.3.

3.2.1 Typical exam questions

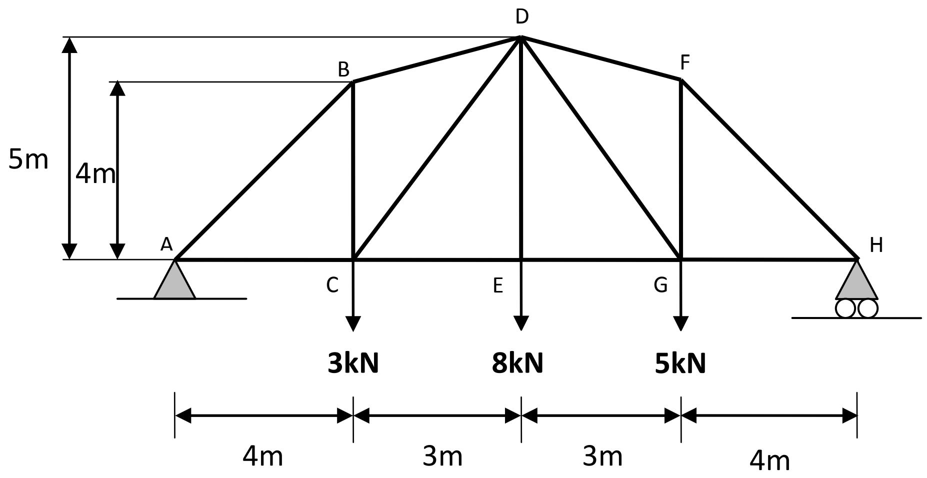
Due to restrictions on releasing examination papers to the public, it is not possible to reproduce actual examination paper questions here. Instead, example questions drawn from the common text books that are similar in scope and content to questions in the exams are presented here to provide greater clarity on the examination paper for the reader.



Two cars collide head on, the car on the left is 1600kg and is coasting at 40km/h, the car on the right is 900kg and is coasting at 60km/h. The cars become entangled after the collision. Determine:

a) The velocity of the entangled cars immediately after the collision
b) The magnitude of the impulse during the impact
c) The loss of energy (ΔE) due to the impact.

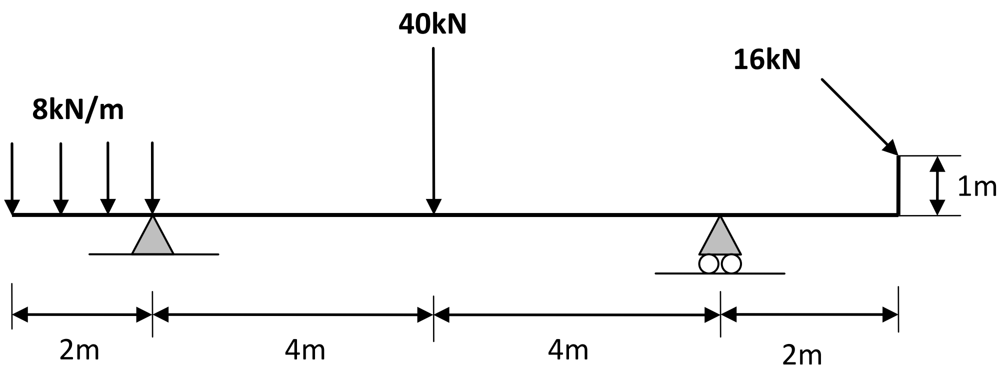
Figure 3.2 Typical conservation of momentum question style



The truss is supported by a pin at A and a roller at H. Determine:

a) The reactions at A and H
b) The FBD for the joint H and determine the forces in members GH and FH
c) Determine the forces in members CD, BD, and CE using the method of sections. Shoe the FBD for your chosen section.

Figure 3.3 Typical truss analysis question assessing both the method of joints and method of sections.



For the beam shown above draw the axial force, shear force and bending moment diagram. Mark all important values on each diagram.

Figure 3.4 Typical example of a more complex internal force statics question.

These exam questions are based on typical problems from major textbooks used in engineering Mechanics courses (Gray, Costanzo, & Plesha, 2010; Hibbeler, 2009; L. G. Meriam & Kraige, 2007), described by Litzinger et al (2010, p. 337) as *well structured and knowledge rich*. The questions are typically designed to take students around half

an hour to complete, and are the same type as those used in the tutorial classes for each of the four courses. The majority of questions in each of the exam papers followed this format.

3.3 Results

3.3.1 Exam paper content

The content of each of the exams generally reflected that which is presented in table 3.4. UOW and UTAS both had equal components of statics and dynamics type questions, while AMC was predominantly dynamics, and UTS was statics only. This limited the number of exam questions that were similar across all four exam papers. The topic areas where similar questions arose are shown in table 3.5. There were additional mathematical topics and skills which were universal such as simultaneous equations, integration and differentiation, and trigonometry. These are not reported here as they are assumed knowledge in these Mechanics courses, and students' knowledge and skill in these are not necessarily a result of teaching in the course. However, students understanding of these areas of mathematics may improve as a result of their application in Mechanics, and their proficiency in these areas may affect their outcome. Therefore these issues have been considered in more detail in chapters four and five.

Table 3.5 Concept similarities across the four exam papers (only concepts existing in more than one paper are shown here)

Common Key Concepts	***UTAS***	***UTS***	***AMC***	***UOW***
Force/moment resolution	✓	✓	✓	✓
Force/shear/BM	✓	✓		✓
Centroid & second moment of area	✓	✓		✓
Acceleration/velocity/distance	✓		✓	✓
Linear momentum			✓	✓
Stress/strain		✓	✓	
Conservation of energy	✓		✓	✓
Angular dynamics	✓		✓	
Truss analysis		✓		✓

The only concepts assessed that were found to be common across all four exam papers were basic force and moment resolution. The commonality of resolution of forces is unsurprising as this covers the basic laws of motion fundamental to any study of Mechanics. The universality of moments (or torque) was also as expected as the concept of a moment in Mechanics is fundamental to solving problems involving rigid bodies (such as structures, mechanisms, levers etc.). After this the topic areas become more divergent, splitting into concepts and analysis procedures typically associated with statics and dynamics.

The three examination papers with a focus on statics (UTS, UOW, UTAS) all included questions involving internal forces, shear and bending moment, and the construction of diagrams representing these for simple beams. Each of the three papers also included a question on the second moment of area of a compound shape. Stress and strain were covered by the UTS paper and the paper that focused mostly on dynamics at AMC. Truss analysis appeared only in the UTS and UOW papers, even though this analytical method is also taught in the UTAS course.

The three papers that included a dynamics component (AMC, UTAS, UOW) each had questions relating to the conservation of energy and the relationship between distance, velocity and acceleration. Analysis of curvilinear motion with the use of polar coordinates (described in table 3.6 and angular dynamics) is taught at three institutions but was only assessed in two of the final exams.

It can be seen here that compared to the content in table 3.4 and the learning outcomes described in 3.1.1, none of the final exams covered every topic in the course, although the four papers combined did provide a reasonably complete spectrum of what students may be expected to learn in first year Mechanics courses.

No major differences in terminology were noted in the comparison, aside from some of the symbols and letters used to denote certain values. These symbols and letters tended to be contextualised within the question wording or diagrams, so did not pose a challenge for the four academics reviewing the papers.

3.3.2 Perceived levels of difficulty

While reviewing each paper, each of the academics rated the difficulty of each question as either: Straight forward (1); moderate (2); or, challenging (3). This rating was

subjective, and intended to be a comparative indicator rather than an absolute measure of difficulty. This was reflected in the outcomes of the exercise, where just over one third of all questions prompted disagreement between the academics over the level of difficulty. In several cases this disagreement was split between straight forward and challenging. One truss analysis was rated 1 by two reviewers, and 2 and 3 by the other two reviewers. Another question relating to distance/velocity/acceleration was only rated by two reviewers, who nominated 1 and 3 for the level of difficulty. A similar question, also involving projectile motion, was rated at 1, 1, and 3 by three reviewers.

There was some variation in the proportion of questions from each exam paper that elicited disparate difficulty ratings. In the AMC paper, only one of the 14 question components was rated differently by two reviewers. In stark contrast, six out of the eight question components in the UTAS paper received different ratings. Next was UOW with different ratings for four out of the seven rated components, followed by UTS with only two out of the seven rated components.

Figure 3.5 shows the average difficulty ratings for each paper. These are fairly consistent with all papers rated at just above a moderate level of difficulty. The same can be said of each reviewers' average rating. Figure 3.6 shows their average ratings at moderate or slightly above. This suggests that according to the reviewers, the four papers are roughly equivalent in terms of overall difficulty.

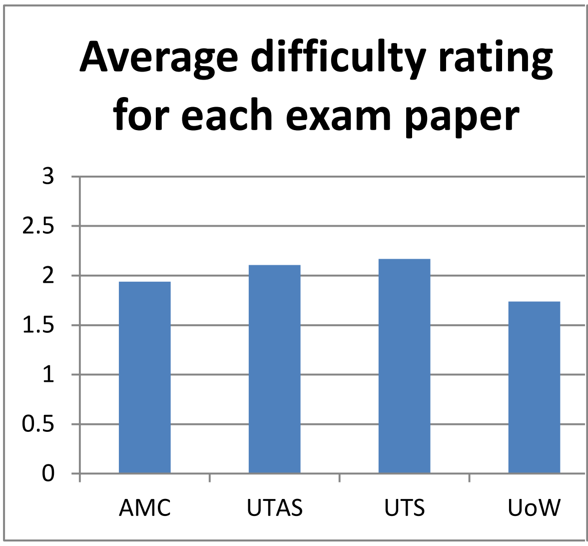


Figure 3.5

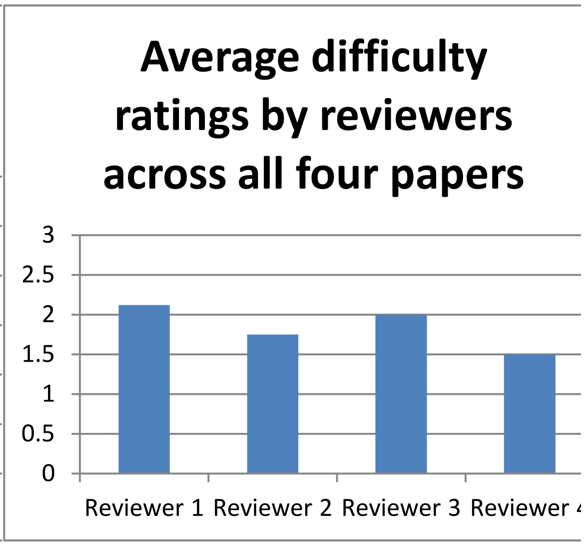


Figure 3.6

Figure 3.7 shows the average ratings for the topic areas where there were similar questions in two or more papers (from table 3.5). This provides the most direct

comparison of the perceived levels of difficulty across similar questions from different papers. There was a much greater disparity between individual questions than there was between exam papers overall. This is important to consider when comparing students' responses to these questions as their performance on a question may be related more to the difficulty level than understanding the concepts they aim to assess.

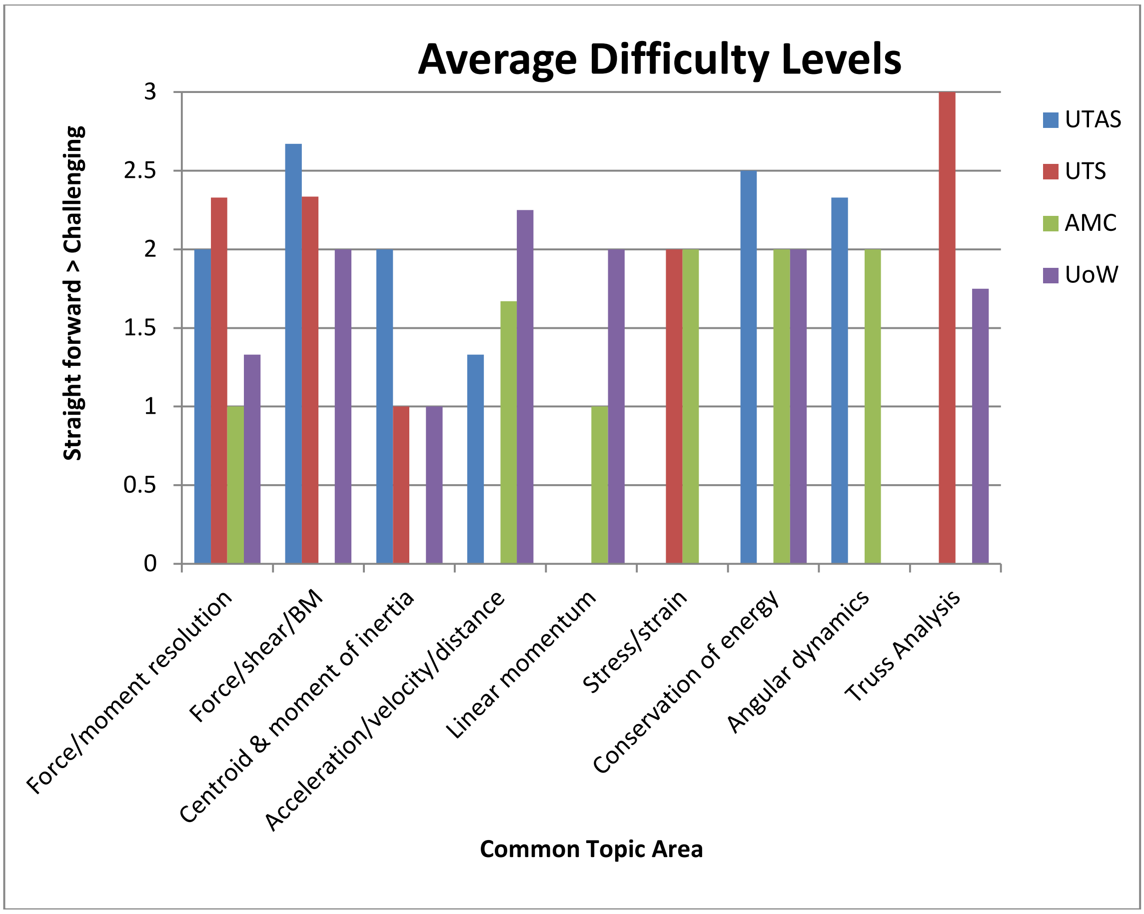


Figure 3.7 Average levels of difficulty compared between common questions

These results indicate that the difficulty of a particular question in a final examination may depend on individual perception, so questions that appear straight forward to one person may be seen as challenging by another. Moreover, the academic's understanding of what 'straight forward' or 'challenging' is could also differ.

These disparities in perceived difficulty may simply be an artefact of the review process itself because in each case, the examination papers were written with full knowledge of the course and what was covered in class or in previous assessments. The developer of the examination paper also had the benefit of feedback from previous assessments, and so was able to estimate how students might perform on a given question. When reviewing other papers, the reviewer has little knowledge of the context from which the

paper was derived, and so is in a disadvantaged position for judging how difficult a question is in context. This issue around perception of difficulty relates to a study by Streveler et al (2006) which found that academics can often misjudge how much their students understand, and their ability to solve problems. In this case any discussion around the levels of difficulty only serves as an indication of the assessment standards in each Mechanics course. As Figure 3.7 indicates, the standards for assessment in the four Mechanics courses are comparable. Figure 3.8 indicates that any differences the reviewers had in perceptions of difficulty are evened out over all the examination papers.

3.3.3 The reviewers' comments

Below are personal reflections on the exam comparison exercise from each of the academic reviewers. These were captured at the time of the comparison in 2008 to record the reviewers insights into other Mechanics assessments. The quotes here are drawn directly from previously published work by the author and the reviewers (Goldfinch, et al., 2008). These reflections focus on the process itself, and also provide interesting commentary on the nature of Mechanics content and how the assessments were developed. The names of the reviewers and the institution to which they belong have been removed in the interests of anonymity.

> As a lecturer of engineering Mechanics, I found identifying key concepts in stage 1 relatively easy as many of the questions clearly fell into familiar categories of a 'centroid' problem or a 'static equilibrium' problem, etc. The majority of questions, especially in statics, were of the convergent type where the examiner clearly expected a unique answer by means of a preferred solution method.
>
> I was surprised by the high level of similarity in the style of questions, content and concepts. In a broader sense, it is suggestive of a high degree of commonality between the teaching programs. Establishment of this 'common' ground is very encouraging, as the workgroup can now focus on the task of improving teaching and learning of engineering Mechanics (Academic1).

I welcomed the opportunity to compare topics included in the various final exams as well as the level of difficulty of the question posed. This process initiated reflection on my own teaching, about what I regard as the most important learning outcomes in this subject and why I regard them as the most important. Because the process used the final exams as the vehicle for comparison, it focused attention on how exam questions were worded – was the question unambiguous? Did the wording lead the student to provide the answer I was expecting or was another interpretation possible? I try to set exams so that an 'average' student can earn 50%, but I don't want this 'average' student earning say 80%, so there have to be some discriminators as well... the benchmarking exercise has leant some weight to a proposed curriculum renewal process in the Mechanics area. One of the main benefits of the exercise was the establishment of a small 'community of practice' in teaching engineering Mechanics to, hopefully, generate mutual capacity building in this subject area which is fundamental to so many subsequent engineering subjects (Academic 2).

Academics can tend work very much in isolation. The background to our expectations of required teaching material and knowledge can derive from our own experiences as undergraduates. Are we then stuck in a time warp? Do we teach what we were taught; at the level that we were taught (though usually lamenting that it was harder back in our day)? So this project was a great opportunity to see what others are teaching at universities around the country and what their expectations are of students at the end of the unit.

It was straightforward to identify the key concepts in each question; though I was not sure to what level of detail to work to. It soon became apparent that questions contained other important factors which would not be captured by the Mechanics concepts, such as the mathematic content and visualisation and spatial awareness skills. Since we had not commenced with a common clearly defined set of terminology, it was slightly harder to categorise the questions into groups assessing similar content.

> Ranking the difficulty of the questions was the most challenging part of the study. I was a little nervous that I would rank a question as extremely difficult only to have all my co-researchers mark it down as a very easy! Though the whole project has progressed in a very supportive way and this initial study has helped establish good collaboration for further work. Once all the results were circulated amongst the team it was clear that generally the exam papers have been set at a similar level, but each contains questions with a range of difficulty.
>
> I found taking part in this study to be a valuable experience and it will help me with my teaching in the future; for example I've picked up some nice ideas from my co-researchers that I'll certainly be using (Academic 3).
>
> The opportunity to have colleagues from other institutions comment on my exam questions has been very valuable. It has also been informative to review papers from these colleagues. Comparing difficulty levels of the questions has led me to better understand how to create different levels. The exercise has also shown that the background of the exam setter influences both the type of question set and how they perceive its difficulty. It is comforting to note that while there are subtle and significant differences between the examinations papers, there is general agreement that they represent an equivalent set of tests of student's knowledge and understanding of Engineering Mechanics.
>
> Sharing our reflections on what we have done during the benchmarking process has added to my understanding of how to ask the right question. It takes considerable design effort to formulate questions that truly test a student's grasp of a concept without being blurred by other aspects of the problem. Predicting what mistakes demonstrate specific misunderstandings is another factor in question design (Academic 4).

The academics reflections here reiterate views expressed by academics involved in the external examiner system in place in the UK (Bjørn, Ellen, & Nils Henrik, 2008; Hannan & Silver, 2004). The strong theme from these reflections is that the academics all felt they benefitted from seeing other exam papers. The reasons given for this,

reassurance of their approach to setting exams and ideas for developing future ones, confirm that Mechanics examination papers, are usually developed within the institution for that institutions own context, and will inevitably be different to some extent. This is also confirmed by the differences in overall subject content and the different perceptions of question difficulty.

Most importantly for this research was each academic's acknowledgement of the broader similarities between each paper. The academics remarked that while there were differences, all four papers were seen as appropriate and indicative of wider assessment practices in engineering Mechanics.

3.4 Chapter summary

This chapter has developed a basic picture of what students might be expected to learn in a first year engineering Mechanics course, and how these courses are run. The benchmarking exercise was not exhaustive, and relied on the four participants own opinions and experience with the researcher moderating the process. While it is possible to conduct a more rigorous approach to comparing assessment standards, the process used was similar to that which is applied and widely accepted in the UK external examiner system (Bjørn, Ellen, & Nils Henrik, 2008; Hannan & Silver, 2004). The process used served it's purpose of a general exploration of the 'teaching context' as described by Biggs' 3P model. Comparing these four typical courses and their major assessment component also created an overview of the way in which students are required to demonstrate their learning in order to pass an introductory Mechanics course.

There were several challenges in developing a definitive answer for the sub-question in this chapter, *What are students expected to learn in first year engineering Mechanics?* Firstly, the specific content of each course was not the same. There were fundamental commonalities between courses, most notably Newtons three laws of motion, but other specific topics differed. The result is that when talking about 'engineering Mechanics', or specifically 'first year engineering Mechanics', these terms do not imply a universal set of topics, concepts and analytical methods to be learnt by all students.

Secondly, differences in in-session assessments and academics' perceptions of difficulty showed how learning outcomes were measured differed from course to course. This

implied that, as per the 3P model, there should be a direct relationship between 'product' and 'presage'. This highlighted the need to discuss learning outcomes and fail rates Mechanics with reference to their context.

Thirdly, while pedagogy was broadly similar at each of the four institutions, there were differences in the way classes were run, assessments developed and marked, and how students were assisted outside of class. This also aligned with the 3P model, where a relationship appeared to exist between learning-focused activities (process) and teaching context (presage).

However, despite the differences between the four Mechanics courses, the fail rates for each course were similar and very high. This suggested that learning focused activities, informed by teaching context, were not delivering the desired learning outcomes. Exploring the content and assessment practices here did not provide sufficient insight into how these related to the high rates of failure. Having established a greater understanding of what students are expected to learn in these Mechanics courses, an investigation of how students respond to these expectations, or the learning outcomes, was the next step in exploring Mechanics teaching and learning.

Chapter 4

Analysis of student learning outcomes

4.1 Introduction

A key aim of this thesis was to identify why so many students fail Mechanics. An important factor in this was developing an understanding of what it is that causes problems for students at the topic level. Litzinger et al (2010) and Taraban et al (2011) used ‘think aloud’ studies to explore the strategies students use and the challenges they face in solving Mechanics problems. These studies provided rich data, however, the range of topics that can be explored and participants in this type of study limited the scope to a small selection of target topics. The nature of the data collection also limited the ability to generalise the results to an entire cohort.

Several studies in engineering Mechanics education have explored students’ performance in engineering Mechanics through the use of concept inventories (Hestenes & Wells, 1992; Hestenes, et al., 1992; P.S. Steif & Dantzler, 2005; P. S. Steif, et al., 2005). However, as Steif, Dollár, & Dantzler, (2005) reported, the results in these concept inventories only have a moderate correlation to performance in related Mechanics examinations. While results in these inventories can be predictive of exam performance, they do not tell a complete story about what exactly students have difficulty with overall when studying Mechanics.

In contrast, final examinations scores tended to correlate strongly with overall subject performance. Table 4.1 shows the Pearson correlation between student performance in the final exam and overall subject performance at UOW in 2007.

Table 4.1 Pearson correlation between overall performance in the UOW subject ENGG152 and students’ performance in the final examination.

	ENGG152 exam mark and overall mark
Pearson correlation (r)	0.943
Significance (two tailed)	0.000
n	274

This is unsurprising given the bias towards quiz and final exam assessment formats identified previously in 3.1.1. Final examinations make up the largest proportion of assessment at all four of the case study institutions, ranging from 50-60% of the total subject assessment. As a result, they contribute in large part to the high fail rates in Mechanics courses that this research is investigating.

The previous chapter presented an overview of what topics students are expected to know by looking at final examination papers from each institution, and also the difficulty levels of these as perceived by academics. The format of each of these exams was also comparable. Hence, to develop an understanding of what it is that students find the most challenging in introductory Mechanics courses, the final exam assessment was selected as the most appropriate source of data. By exploring students’ responses to the final exam questions in detail, the research was able to work directly with the most significant source evidence currently used to determine students competence in introductory Mechanics.

This chapter describes the framework, method, and results of a detailed analysis of students work from four different institutions, informed by the sub-question:

What are the key topic areas students have difficulty with?

The work involving analysis of students examination transcripts was covered under the University of Wollongong’s Human Research Ethics Committee (approval no. HE08/017, see appendix B.1), and ratified by the UTS and UTAS HREC’s (approvals 2008-131A and H9967 respectively, see appendix B.2 and B.3).

4.2 Method

4.2.1 Analytical framework

To analyse students final examination transcripts effectively, it was important to minimise the influence of the preconceptions and biases of the researcher. This was a key consideration throughout this research as the author had previously struggled with engineering Mechanics himself. The review of common introductory Mechanics textbooks in 2.3.3 identified Mechanics problem solving approaches recommended by the authors. The subtle variations in these recommendations also suggests there are different ways of viewing Mechanics problems and solution techniques that are

influenced by personal experience. This highlighted the need for a structured approach to analysing exam questions and students responses.

It is common in education to use frameworks or diagrammatic representations of teaching and learning processes. One such example described in 2.4 is the Biggs 3P model. These models were developed to help the researcher, or educator, to structure their understanding of a scenario and limit the impact of personal opinions and biases because a framework for analysing exam questions and students' responses in detail was needed.

The identification of a suitable framework drew heavily on the work of Mosely et al (Mosely, Baumfield, et al., 2005; Mosely, Elliott, Gregson, & Higgins, 2005). Mosely and others identified 55 frameworks for thinking from authors around the world and provided a brief summary of the 35 most prominent ones. They also provided a useful critique of the validity and suitable applications of these frameworks. This work provided a valuable advanced starting point in the search for an appropriate framework for analysing the examination papers and transcripts.

A well known framework for understanding the levels of cognition required for a given task is Bloom's taxonomy (Bloom, 1961). Bloom's taxonomy lists cognitive process verbs in six different categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Anderson and Krathwohl's later revision of Bloom's taxonomy takes into account the various criticisms of the taxonomy and, in a more systematic way, has developed a revised version (Anderson & Krathwohl, 2001). Both of these frameworks are widely used in the development of learning outcomes and assessment standards (Nightingale, Carew, & Fung, 2007). When applying these frameworks to the typical questions and solution steps in the Mechanics final examination papers, most fitted into the analysis domain, as described by Bloom (1961) and Anderson and Krathwohl (2001). These frameworks were not particularly helpful for analysing the current form of mathematical solution type questions from the exam papers because they would not help to break the questions down into finer components.

Biggs and Collis' Structure of Observed Learning Outcomes (SOLO) Taxonomy (J.B. Biggs & Collis, 1982) was another widely accepted framework considered. This model aims to map how a student's understanding develops through a series of five stages of

increasing complexity: Pre-Structural; Uni-structural; Multi-structural; Relational; Extended abstract. The SOLO taxonomy had limitations in terms of analysing students' responses to final exam questions. The nature of many questions in the examinations limited the level within the taxonomy at which students could demonstrate their understanding. In addition, most questions were not structured in such a way that they could effectively discern between different levels. In a similar way to Blooms taxonomy, it would be difficult to use this framework to make any distinction between students' level of understanding, or what specific topics they were struggling with.

The Van Heile framework (Van Hiele, 1986), described in brief in Chapter 2 in its application to Mechanics teaching (Sharp & Zachary, 2004), was also considered, given the precedent for its use in Mechanics. This framework, however, was developed to focus on the early steps in Mechanics problems that involved spatial ability and the creation of geometric representations of Mechanics problems. The framework does not take into account the later steps of solving Mechanics problems which involve mathematical analysis.

In light of the limitations of these frameworks in their application to the existing examination format, a framework by AJ Romizsowski (1981) was identified as having potential. This framework, shown in figure 4.1, is a component of his analysis of knowledge and skills. This component focuses only on knowledge and distinguishes between different types of knowledge. This framework was particularly appealing because of its reference to terms commonly associated with engineering problem solving like 'concepts', 'rules', and 'algorithms'. Further exploration on how these terms were defined in their application within this framework confirmed this was an appropriate model. Romiszowski also proposed a model for 'Skills' development, but it was not considered for this research due to the exam format's limitations in assessing skill levels (i.e. speed, accuracy etc.).

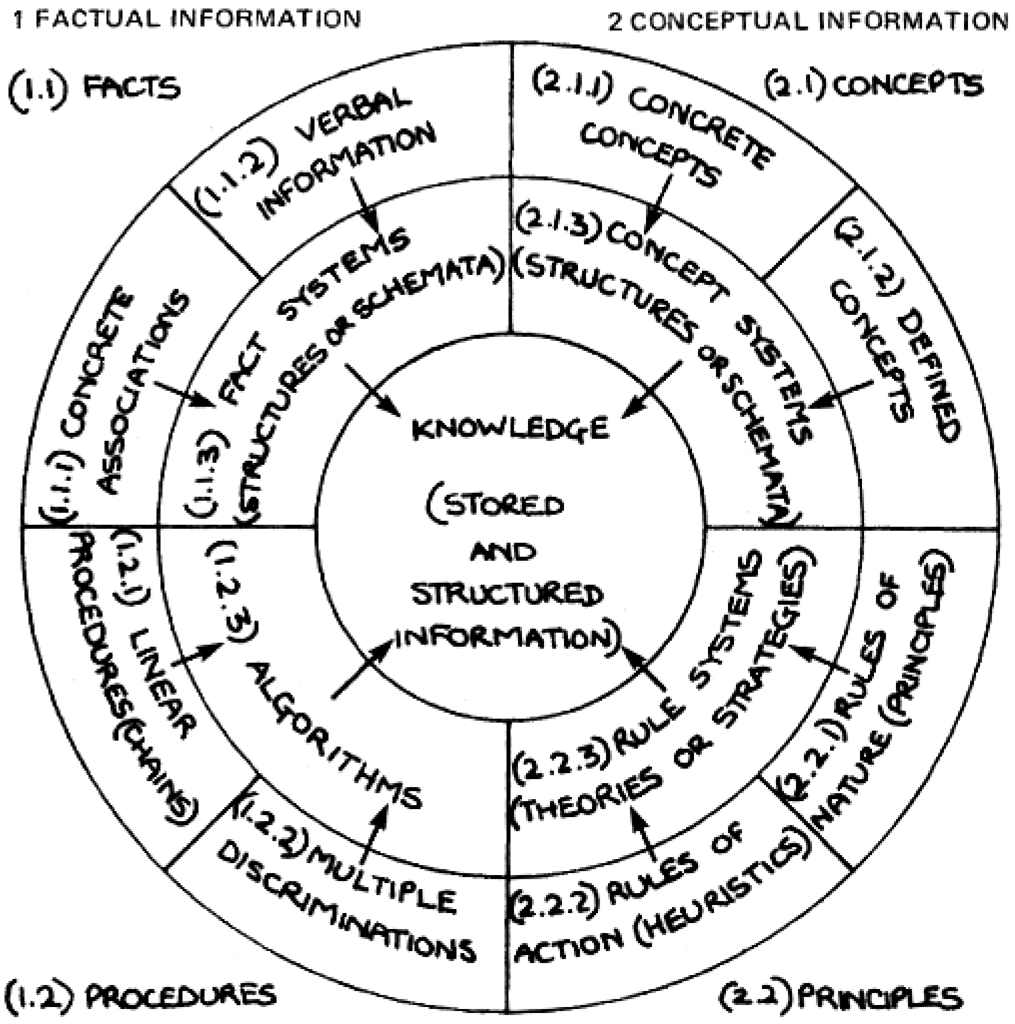


Figure 4.1 Original Romiszowski knowledge schema (Romiszowski, 1981, p. 243)

4.2.2 Description of the Original Romizsowski Framework

Romiszowski's knowledge schema was derived in the context of a systems thinking frame of reference (Romiszowski, 1981, pp. 5-11). It draws from the earlier work of Williams' (1977) revisions to Blooms Taxonomy. A key difference between Romiszowski's and Bloom's work is that Romiszowski (1981, p.241) separates knowledge from cognitive skill. In this framework, knowledge is defined as the "*information stored in the learners' mind… akin to the normal use of the word when we say we 'know' something*". This no-nonsense definition, is left slightly open to interpretation by the reader. The author's interpretation of 'knowledge' for this purpose is clarified as the information gained by the learner over the duration of the Mechanics course that is able to be utilised and reproduced for the purpose of the assessment task provided, in this case, the final examination. Given the 'snapshot' nature of the

examination format, the only ‘knowledge’ that can be considered in this chapter is that which can be captured by the final exam.

Romiszowski (1981, p.241) defines ‘skill’ separately as “*actions (physical or intellectual) and indeed ‘reactions’ (to ideas, things and people) which a person performs in a competent way to achieve a goal. In practicing a skill, one uses certain items of knowledge that are stored in the mind”*. Without the necessary controls and measures in place to evaluate a student’s skill in solving Mechanics problems (time to completion, directness of solution, error frequency, etc.), the focus was instead only on the knowledge demonstrated in practicing a skill.

Romiszowski then separates knowledge into two broad categories characterised in different ways:

a) Remembering (factual knowledge)

- i) Knowing objects, events or people (verbal and concrete information)
- ii) Knowing what to do in certain situations (procedures)

b) Understanding (conceptual knowledge)

- i) Specific concepts or groups of concepts (recognising phenomena, being able to describe it)
- ii) Rules or principles that link concepts or facts in certain ways (using one phenomena to explain another)

From here it became clear that this framework is one derived with application to mathematical and scientific knowledge. Figure 4.1 is the diagrammatic version of this framework extracted directly from the original 1981 text.

This framework was considered to be well suited to engineering Mechanics topics as it accounts for the range of steps covered in a typical examination question. The distinct domains around factual knowledge, procedural, conceptual and principle knowledge are also an appropriate fit with the way in which first year engineering Mechanics content is typically referred to (see Chapter 2). Some information is presented as facts only, to be explained in later years of study, while other instruction explains concepts of Mechanics, rules for solving problems and solution procedures. All of these aspects of knowledge are assessed to some extent in the examination papers at the focus of this

research. A definition of how each knowledge type was applied to engineering Mechanics is dealt with in 4.2.4 and table 4.2.

4.2.3 Modified Romiszowski Mechanics Framework MRMF

The original framework still posed some difficulties for analysing the Mechanics examinations. The two high order domains of knowledge, factual and conceptual, shown at the top of figure 4.1 are described in 4.2.2. Their distinction from two of the four lower order domains, 'facts' and 'concepts', is not made explicit within the diagram itself. The similarities between these overarching domains and two of the four subsets (facts and concepts) was somewhat confusing to the author. Since the purpose of using a framework from the outset was to clarify the analytical process, these issues could have affected the clarity of the outcomes. Taking this into account, a minor redevelopment of the framework was conducted and is shown in Figure 4.2. This update merely removed the highest order domain to make the four main aspects of knowledge, Facts, Concepts, Procedures and Principles, clearer. This modified framework was then referred to as the Modified Romiszowski Mechanics Framework, or MRMF, to distinguish it from the original but also to clearly acknowledge its origins. The MRMF does not alter the integrity or intentions of the original knowledge schema, it merely brings to the fore a more detailed discrimination between knowledge types.

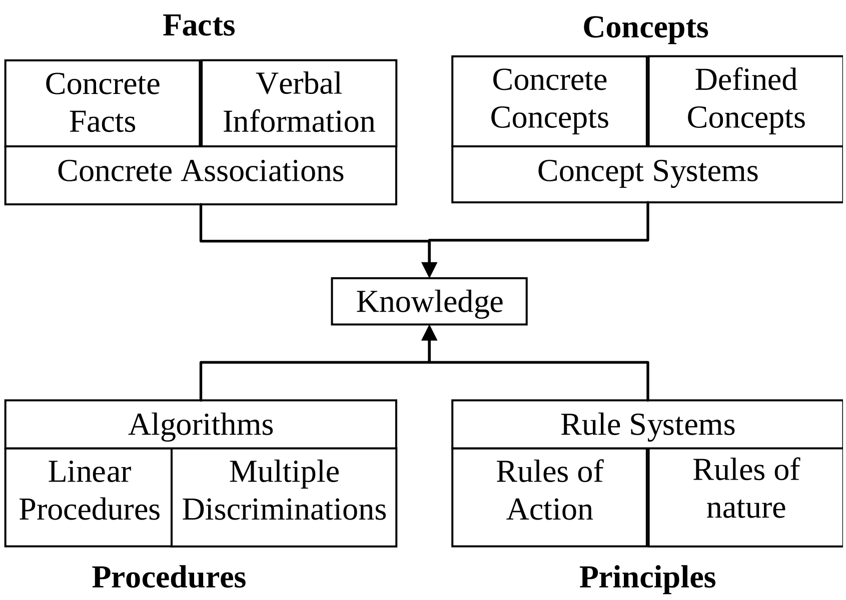


Figure 4.2 Modified Romiszowski Mechanics Framework (MRMF)

4.2.4 Application of MRMF

Applying the framework to the analysis of examination papers was a multi stage process. A basic, loosely structured exploration of the nature of the content of four examination papers (with one paper differing to the set used here) was carried out earlier in the research and is outlined in Chapter 3. A similar process was subsequently carried out using a much more tightly controlled approach with the aid of the MRMF. The full process is summarised in Figure 4.3, and please note this is in the future tense because it was a planning tool.

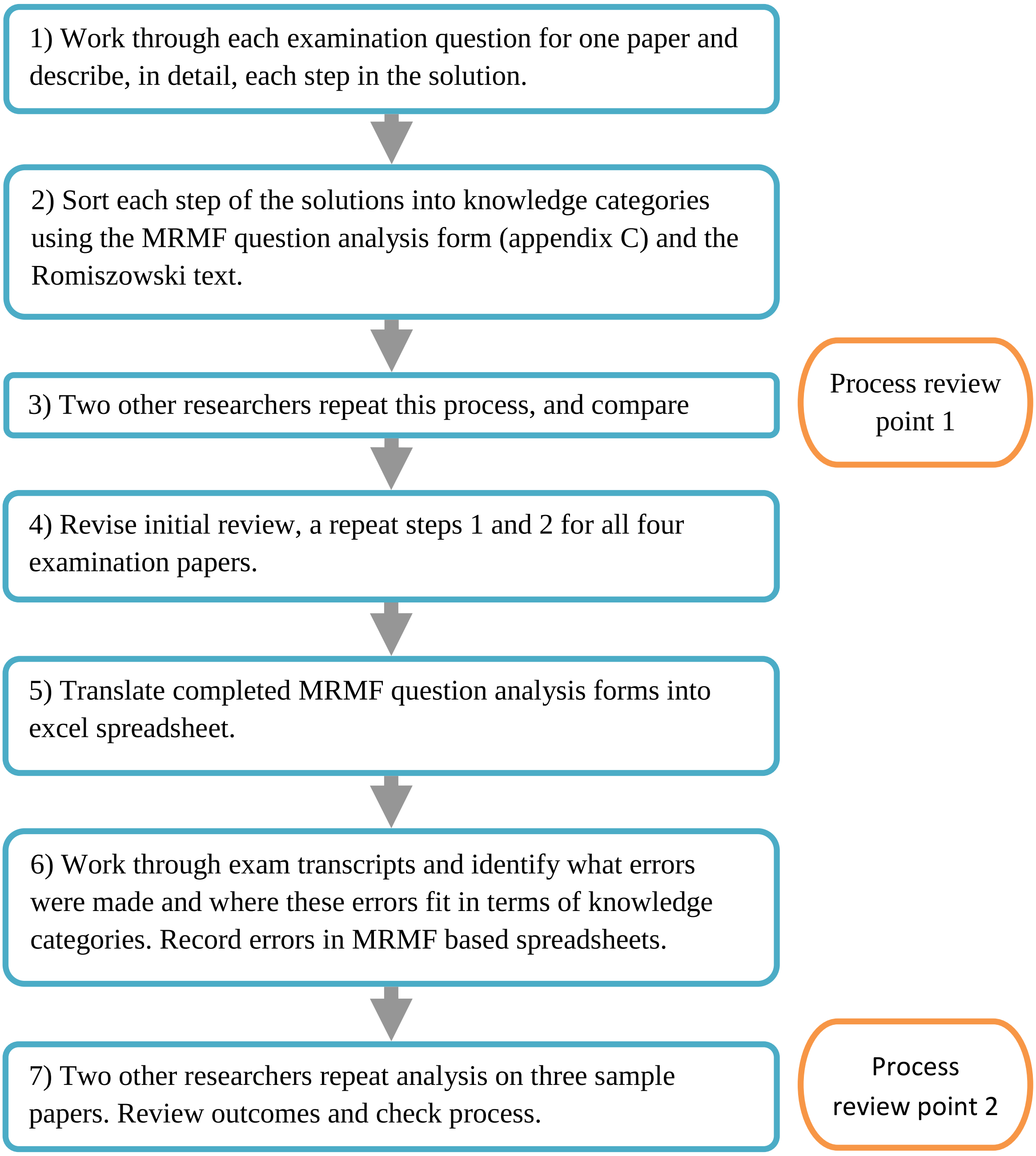


Figure 4.3 Overview of exam paper and transcript analysis

In this process there were two points where the quality of the exam analysis process was reviewed with the help of two other researchers: Dr. Alan Henderson (University of Tasmania) and Dr. Giles Thomas (Australian Maritime College @UTAS). These external process reviews (points 1 and 2) are described in detail in 4.2.5.

Table 4.2 outlines examples of typical solution steps and how they were categorised under the MRMF, as described in step 2 of the exam analysis process (Fig. 4.3). The position that solution steps were placed within the framework matrix was not always as one would expect. The identification of knowledge type was influenced by the nature of the question, not just the knowledge content it was designed to assess. For instance, when considering Newton's laws of motion, one might reasonably assume that these belong in the category of conceptual knowledge, but in one exam question the students were asked to state Newton's three laws of motion. It was reasoned that recitation of the laws did not necessitate true understanding because students could still achieve full marks by simply memorising them as given facts. Thus the solution to this question was placed in the Factual knowledge field.

This occurred in numerous questions, and often the placing of solution steps within the framework was at odds with what might be expected. This demonstrates how the use of the MRMF clarified the way in which exam questions may be interpreted by students, rather than restating what might have been intended by the exam author. The framework was very useful in enabling the researcher to disassociate from the content and their experience/perception of it, and look at what the question is asking from a fresh perspective.

Table 4.2: Definition of framework fields adapted to engineering Mechanics from Romiszowski (1981)

Category	*Sub-category*	*Definition and example*
Facts	Concrete Facts	Things committed to memory from simple observations, and not associated with language. Eg. remembering someone's face, recognition of an object
	Verbal Information	Knowledge associated with language or symbols. Eg. units, terminology, vector notation etc.
	Concrete Associations	Interlinking of facts. Eg. recognising a truss analysis problem, knowing which given quantity is velocity etc.
Concepts	Concrete Concepts	Simple concrete facts tied to understanding. Eg. recognising a cantilever beam
	Defined Concepts	More complex verbal and factual information tied to understanding. Eg. Knowing that a vector has magnitude and direction and the associated terminology
	Concept Systems	Interrelated concepts. Eg. momentum is a product of mass and velocity which in turn require understanding.
Procedures	Linear Procedures	Simple, chain calculations. Eg. substituting numbers into an equation and solving.
	Multiple Discriminations	Distinguishing between information, and solving problems in parallel. Eg. knowing/deciding which numbers to substitute into an equation.
	Algorithms	Complete procedures involving both linear procedures and multiple discriminations. Eg. Truss analysis where several problems need to be solved simultaneously using the correct data and processes.
Principles	Rules of Action	Rule's governing the behaviour or actions of the individual. Eg. identifying all given information a the start of a problem solution.
	Rules of Nature	Rules that explain the behaviour of objects or the surrounding environment. Eg. Gravity is what pulls objects down, forces cause the motion of objects.
	Rule Systems	Strategies and theories. Eg, selecting a particular approach to solving a large problem.

4.2.5 Quality control of the Examination analysis process

The approach used to conduct the examination transcript analysis using the MRMF included two points where the analytical process was reviewed and calibrated. Review point one (indicated in Figure 4.3) was intended to establish whether the MRMF was a useful tool for reliably breaking down each exam question into the components of the knowledge they assess. The MRMF, translated into a question analysis form (see Figures 4.5 and 4.6) was distributed to two other Mechanics educators, Dr. Alan Henderson and Dr. Giles Thomas. An initial discussion on the framework and pre-reading of the Romiszowski text (Romiszowski, 1981, ch. 12) was conducted initially to clarify understanding the MRMF. The three researchers independently worked through one exam paper, breaking each question down into its components and categorising them using the MRMF question analysis form. The paper selected for this was the UOW one because the author, and Dr. Henderson and Dr. Thomas had no involvement in its development. In this paper there were four multi component questions, for which students were given 3 hours 15 minutes to complete under exam conditions. After completing the analysis of all questions, the reviews were compared.

Table 4.3 shows the results of the review for one question of UOW exam paper. The question cannot be reproduced here due to policies on the publication of past papers but it can be seen here that there is a remarkable level of agreement between each of the researchers, distinguished by different coloured text. The only differing result is one step noted under *Rules of action*, where the other two researchers placed this under *Rule Systems*. This indicated only a slight disagreement around the complexity of the rule that was to be applied. This sample question demonstrated the usefulness of the MRMF in understanding the components of Mechanics exam problems.

Table 4.3 Results of the categorisation of UOW examination question solution steps using the MRMF – Highest agreement

Knowledge Categories			
1. Concrete Facts	A. Concrete associations	B. Verbal information	C. Fact systems
	No	Terminology vector notation, vector operations – cross product Vector terminology	Units Units Units
2. Procedures	A. Linear Procedures	B. Multiple discriminations	C. Algorithms
	vector cross product (formula sheet) translate unit vector Calculating magnitude of vectors, numerical operations, evaluating determinant Calculating unit vector	determine position vector calculate unit vector Interpreting dimensions from diagram Calculating moment using vectors and cross product, and using dot product	
3. Concepts	A. Concrete concepts	B. Defined concepts	C. Concept systems
		use coordinate system Coordinate systems Coordinate systems	moments Moment of Forces Vectors – relationship between forces and position to define moment
4. Principles	A. Rules of nature	B. Rules of action	C. Rule Systems
	moment = force x distance Force Forces and moment	calculate moments from forces using vector operations	Calculating moments using vectors ? Using vectors to solve moments

Table 4.4 presents the results of the comparison for another question in the UOW examination paper. This example shows the lowest level of agreement between different reviewers from the four questions analysed. In this instance, disagreements were again limited to differentiating levels of complexity and subsequently categorising solutions steps at different levels, but still within the same knowledge domains (Concrete facts,

procedures etc.). This issue could have been carried over from the different perceptions of difficulty identified in 3.3.3, but these differences were more clearly defined using the MRMF, and it was easier to discuss why different perceptions of complexity existed and to then negotiate the final level for each solution step.

Table 4.4 also shows the different levels of detail to which each reviewer broke down the question solution steps and recorded them in the table. This also suggests differences in the reviewers separation of steps in the problem solution.

Table 4.4 Results of the categorisation of UOW examination question solution steps using the MRMF – Lowest agreement

	Knowledge Categories		
1. Concrete Facts	A. Concrete associations	B. Verbal information Definition of second moment of area, parallel axis theorem, areas	C. Fact systems area formulae 2nd mmt area formulae parallel axis theorem Coordinate systems, units Formula for calculating I of rectangle Equations for summing I
2. Procedures	A. Linear Procedures 2nd mmt area calculation procedure Numerical operations? Areas of sections finding distances from centroid 2nd Moment of areas for each section	B. Multiple discriminations	C. Algorithms Evaluating moment of inertia
3. Concepts	A. Concrete concepts	B. Defined concepts Centroid, second moment of inertia Centroid/neutral axis	C. Concept systems
4. Principles	A. Rules of nature	B. Rules of action Separation of sections for I calculation	C. Rule Systems Calculating moment of inertia

In terms of understanding the components of typical exam transcripts and the knowledge they require, the MRMF was shown to be a useful tool. This simple, qualitative exercise indicated that it is a reliable tool for objectively breaking down each question, and for the purpose of this component of the research, the MRMF was an appropriate framework.

Next was a comparison of the outcomes between the three reviewers for the analysis of four sample student examination transcripts, process review point two in Figure 4.3. Table 4.5 shows the results of an independent evaluation of one sample exam transcript with the three colours again representing each of the three reviewers. In this format the comments were limited to the four broad knowledge types. A 5^{th} domain was also added at this point, general mistakes, to provide space for recording errors that appeared to be simple mistakes such as mixing up terms mid calculation, or calculating an answer that is the result of entering an incorrect decimal place into a calculator. These were mistakes that were deemed not to be linked to any specific knowledge type.

In this process there was substantially more variation in the reviewers interpretation of the mistakes made by students, although the comments made did translate well to the MRMF mapping of each examination question. In discussing this problem, the three reviewers considered that this could be a practice issue. As in normal examination marking, consistency in the identification of errors in students work can improve as more papers are assessed. This outcome of the review was taken into account in the full exam analysis, where the first 10-20 transcripts in the sample batch for each of the four exam papers were analysed twice to improve consistency. The full detail on how errors were categorised for each exam is included in Appendix C. A summary of the distribution of knowledge types in each paper is presented and discussed in 4.3.1.

Table 4.5 Comments on mistakes made in one sample examination transcript, reviewed by three researchers independently.

Q No.	General mistakes
3a	Didn't prove zero SF location
	Factual Errors
1a	C - No units
3	C – formulae incorrect
1	Missing units
1c	No units
	Procedural Errors
1b&c	A - Vector product
2	Resolving forces
3	B –SF & BM wrong
	A – 2nd mmt area incorrect
1	Error in calculating unit vector
2	Errors in determining internal forces
2c	included some forces twice in summing moments and used incorrect distances
	Conceptual Errors
1a	B–coord system error
	FBD error
1	Does not understand how to evaluate vector cross product
2	Incorrectly identified tension and compression
3a	Did not understand relationship between shear and moment – bmd contradicts shear fd.
1a	Doesn't seem to understand what position vector is
3b	Doesn't apply method for I of complex shapes
	Principle/Rule Errors
1c	C – Calc mmts using vectors
2	B – tension/compression error
	Incomplete solution – no idea on a problem solving strategy?
1b	Hasn't used r x F = M
1c	No idea how to start 1c
2b	Tension/compression errors
3a	Shape of BMD incorrect, max moments at end of beam

4.2.6 Conducting the analysis

For the two larger institutions (UOW and UTS), a sample of n=50 exam transcripts were taken. Each of these samples consisted of 10 transcripts from the bottom 1/3 by mark, 10 from the middle third, 10 from the top third, and a further 20 randomly selected from the remaining transcripts. This was done to ensure that all levels of performance were included in the analysis, but so the performance range of the sample

was not selected entirely artificially. The cohort sizes of the two smaller institutions (UTAS and AMC) meant that the full population could be analysed, n=52 from UTAS, and n=51 from AMC.

Student responses to each examination question were then analysed in detail. Where errors were evident in students' solutions, they were recorded in the relevant cell in the spreadsheet according to the knowledge types described by the MRMF (see appendix C). In many cases the same type of error was apparent in a student's solutions to several questions. In these cases the error was only recorded once because the research only sought to identify the types of errors made by students, not the quantity of these errors.

This fine grained approach to analysing the transcript went some way to addressing the issue of disparate difficulty levels previously discussed in 3.3.3. By breaking each question down into its components it was possible to separate out the complexities that made one question appear more difficult than a similar one in another paper. For example, three papers contained questions requiring students to find the second moment of area of a composite shape. In Figure 3.7 there is a significant disparity between the rated difficulties of these questions, where in this case the more difficult question required more steps, for which there was more opportunity to make a general mistake. By breaking the solution steps into their components it was possible to see whether students were able to correctly initiate a procedure in the more complex question, but perhaps missed other information which caused them to find an incorrect answer. In this case, the error would be recorded as a general mistake rather than any gap in their knowledge.

This analysis resulted in four separate spreadsheets (one for each Mechanics course) containing detailed data on what errors individual students were making. These spreadsheets can be seen in appendix C.

4.3 Results

The errors recorded for each student were correlated with the mark originally awarded for that students exam transcript. The total number of knowledge-type errors were graphed against students' final mark to check how closely the actual knowledge errors made by each student reflected their recorded performance in the exam. Figures 4.4 to 4.8 illustrate these correlations for each of the four knowledge types, and the overall

identification of errors for the 50 transcripts analysed from UOW. As Figure 4.4 illustrates, there was a very good fit between the number of different errors recorded and the mark awarded by the original exam marker. This suggests that the number of different types of knowledge errors made by students is related to their performance in Mechanics.

Figures 4.5 to 4.8 illustrate the relationship between recorded errors and the exam marks for each of the four knowledge types. These graphs suggest that procedural and conceptual errors are more closely related to the awarded mark than rule or knowledge errors. Errors recorded for factual knowledge only had a weak to moderate relationship to overall mark. This suggests that this knowledge type, one which considers knowledge as information accepted and committed to memory without the need for understanding , was considered less important by the original markers.

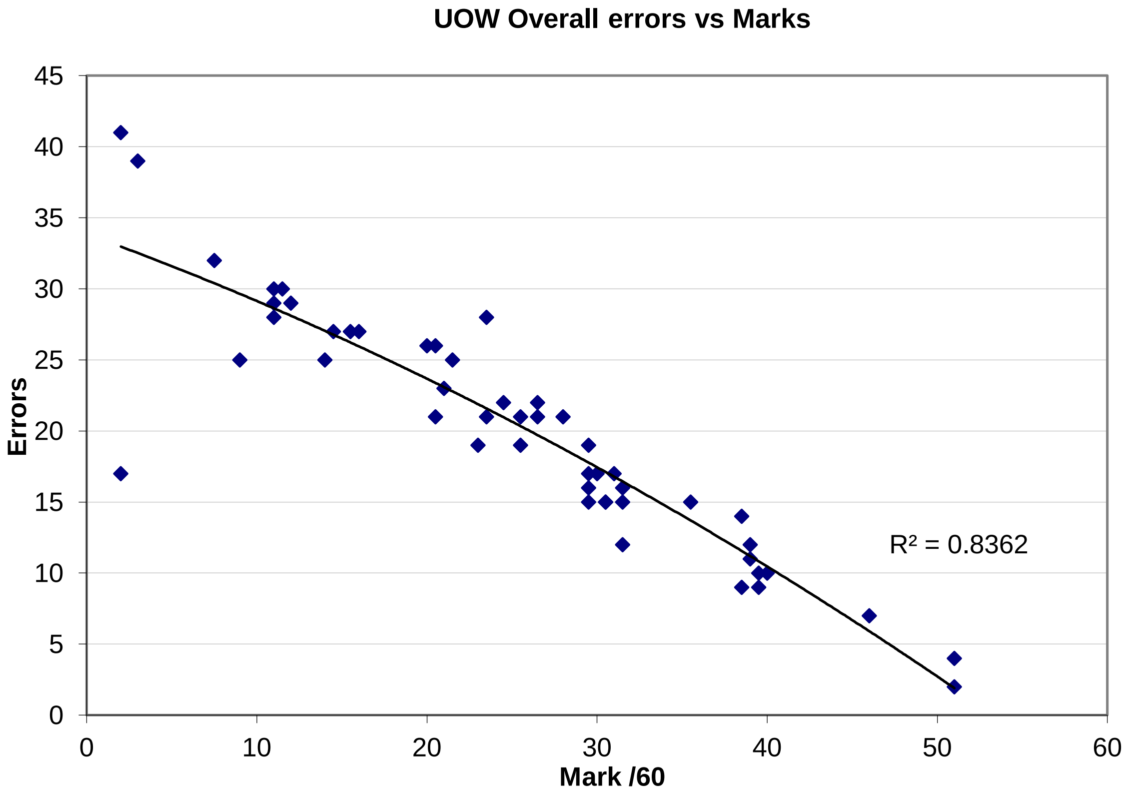


Figure 4.4 All errors recorded plotted against overall mark

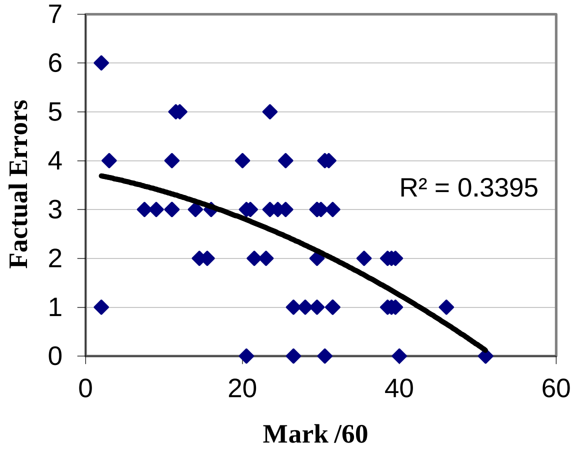


Figure 4.5 Factual knowledge errors plotted against mark

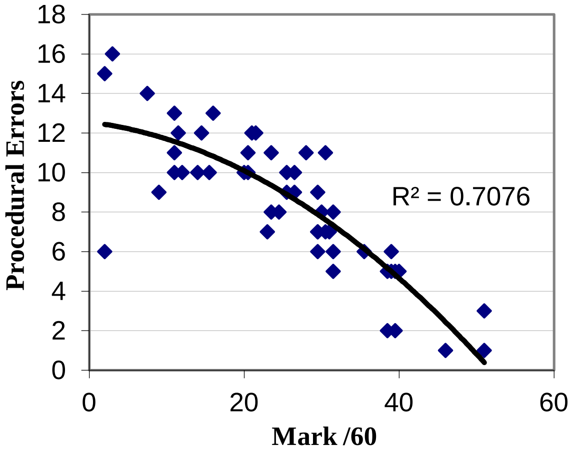


Figure 4.6 Procedural knowledge errors plotted against mark

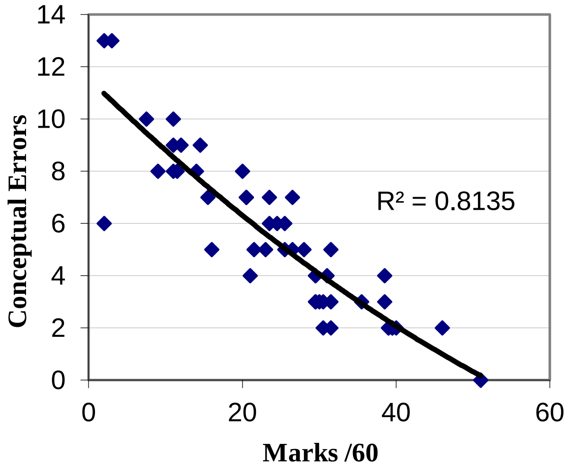


Figure 4.7 Conceptual knowledge errors plotted against mark

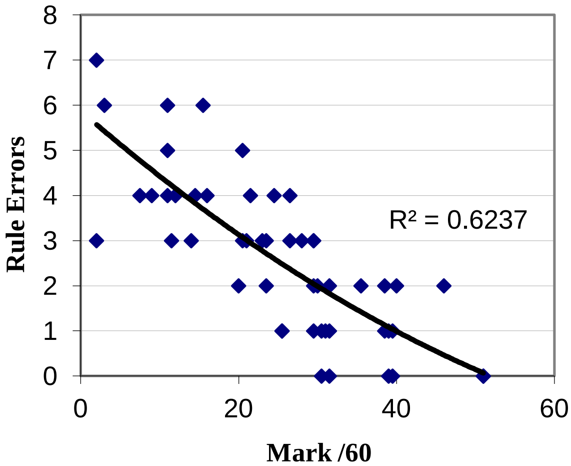


Figure 4.8 Rule knowledge errors plotted against mark

A two tailed Pearson correlation and the statistical analysis software package SPSS (IBM, 2010) was then used to verify these graphs. Table 4.6 shows the strong and statistically significant negative correlation between Procedural, Conceptual, and Rule error types and the marks awarded, and the correlation between different types of errors. This indicates that the errors identified with the use of the framework were very closely related to the outcome of the assessments that determined in large part the success or failure of students studying Mechanics. This was an important outcome for the progression of this research as it meant that when referring to the types of errors made by students, it can be discussed with certainty that this is related to their success in Mechanics.

Table 4.6 Pearson correlations between error types for UOW

		Mark	Fact Error	Procedural Error	Conceptual Error	Principle Error	All Error
Exam Mark	Pearson Correlation	1	-.575**	-.820**	-.899**	-.786**	-.911**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	50	50	50	50	50	50
Fact Error	Pearson Correlation	-.575**	1	.505**	.570**	.387**	.666**
	Sig. (2-tailed)	.000		.000	.000	.006	.000
	N	50	50	50	50	50	50
Procedural Error	Pearson Correlation	-.820**	.505**	1	.808**	.706**	.925**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	50	50	50	50	50	50
Conceptual Error	Pearson Correlation	-.899**	.570**	.808**	1	.804**	.940**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	50	50	50	50	50	50
Rule Error	Pearson Correlation	-.786**	.387**	.706**	.804**	1	.838**
	Sig. (2-tailed)	.000	.006	.000	.000		.000
	N	50	50	50	50	50	50
All Error	Pearson Correlation	-.911**	.666**	.925**	.940**	.838**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4.7 Pearson correlations between error types for UTS

		Mark	Fact Error	Procedural Error	Conceptual Error	Principle Error	All Error
Exam Mark	Pearson Correlation	1	-.531**	-.735**	-.649**	-.310*	-.814**
	Sig. (2-tailed)		.000	.000	.000	.038	.000
	N	45	45	45	45	45	45
Fact Error	Pearson Correlation	-.531**	1	.692**	.405**	.056	.736**
	Sig. (2-tailed)	.000		.000	.006	.715	.000
	N	45	45	45	45	45	45
Procedural Error	Pearson Correlation	-.735**	.692**	1	.568**	.094	.929**
	Sig. (2-tailed)	.000	.000		.000	.541	.000
	N	45	45	45	45	45	45
Conceptual Error	Pearson Correlation	-.649**	.405**	.568**	1	.174	.771**
	Sig. (2-tailed)	.000	.006	.000		.253	.000
	N	45	45	45	45	45	45
Rule Error	Pearson Correlation	-.310*	.056	.094	.174	1	.243
	Sig. (2-tailed)	.038	.715	.541	.253		.108
	N	45	45	45	45	45	45
All Error	Pearson Correlation	-.814**	.736**	.929**	.771**	.243	1
	Sig. (2-tailed)	.000	.000	.000	.000	.108	
	N	45	45	45	45	45	45

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The situation was similar for the other three examination papers. Tables 4.7, 4.8 and 4.9 show the correlations between error types and marks for samples analysed from UTS, UTAS and AMC. The similar correlations between the UOW and UTAS samples are

consistent with the similarities identified between these two courses in the preceding chapter.

Table 4.8 Pearson correlations between error types for UTAS

		Mark	Fact Error	Procedural Error	Conceptual Error	Principle Error	All Error
Exam Mark	Pearson Correlation	1	-.341*	-.911**	-.844**	-.548**	-.942**
	Sig. (2-tailed)		.013	.000	.000	.000	.000
	N	52	52	52	52	52	52
Fact Error	Pearson Correlation	-.341*	1	.304*	.327*	.236	.467**
	Sig. (2-tailed)	.013		.029	.018	.091	.000
	N	52	52	52	52	52	52
Procedural Error	Pearson Correlation	-.911**	.304*	1	.795**	.359**	.940**
	Sig. (2-tailed)	.000	.029		.000	.009	.000
	N	52	52	52	52	52	52
Conceptual Error	Pearson Correlation	-.844**	.327*	.795**	1	.348*	.912**
	Sig. (2-tailed)	.000	.018	.000		.012	.000
	N	52	52	52	52	52	52
Rule Error	Pearson Correlation	-.548**	.236	.359**	.348*	1	.493**
	Sig. (2-tailed)	.000	.091	.009	.012		.000
	N	52	52	52	52	52	52
All Error	Pearson Correlation	-.942**	.467**	.940**	.912**	.493**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	52	52	52	52	52	52

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.9 Pearson correlations between error types for AMC

		Mark	Fact Error	Procedural Error	Conceptual Error	Principle Error	All Error
Exam Mark	Pearson Correlation	1	-.485**	-.769**	-.615**	-.619**	-.826**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	51	51	51	51	51	51
Fact Error	Pearson Correlation	-.485**	1	.439**	.273	.469**	.645**
	Sig. (2-tailed)	.000		.001	.053	.001	.000
	N	51	51	51	51	51	51
Procedural Error	Pearson Correlation	-.769**	.439**	1	.467**	.587**	.850**
	Sig. (2-tailed)	.000	.001		.001	.000	.000
	N	51	51	51	51	51	51
Conceptual Error	Pearson Correlation	-.615**	.273	.467**	1	.540**	.777**
	Sig. (2-tailed)	.000	.053	.001		.000	.000
	N	51	51	51	51	51	51
Rule Error	Pearson Correlation	-.619**	.469**	.587**	.540**	1	.792**
	Sig. (2-tailed)	.000	.001	.000	.000		.000
	N	51	51	51	51	51	51
All Error	Pearson Correlation	-.826**	.645**	.850**	.777**	.792**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	51	51	51	51	51	51

**. Correlation is significant at the 0.01 level (2-tailed).

4.3.1 Identifying the types of knowledge students have difficulty with

Table 4.10 shows the how question solution steps were broken down for each examination paper using the MRMF. The count represents how many different solution steps, or ‘pieces’ of knowledge were established under each knowledge category. The percentage represents this count as a proportion of all the different steps, or ‘pieces’ identified for that paper. It can be seen here that there is a strong emphasis on procedural and conceptual knowledge, with assessment of procedural knowledge dominating in each of the papers. In fact, the proportions of knowledge types are fairly consistent across all papers, despite the quite different questions used in each (see 3.3.1). This would suggest that the types of knowledge required for students to succeed in these four engineering courses are reasonably uniform. Tables in appendix C.1-C.4 show the full break down of how steps were categorised under knowledge types for each institution, and the instances of errors recorded in them.

Table 4.10 Potential error categories for each examination paper

Institution		**Factual**	**Procedural**	**Conceptual**	**Principle**
UOW	(count)	6	17	13	9
	(percentage)	13.33%	37.78%	28.89%	20.00%
UTS	(count)	5	17	10	5
	(percentage)	13.51%	45.95%	27.03%	13.51%
UTAS	(count)	5	18	14	5
	(percentage)	11.90%	42.86%	33.33%	11.90%
AMC	(count)	7	17	11	6
	(percentage)	17.07%	41.46%	26.83%	14.63%

Table 4.11 shows the spread of all errors made by students in the sample for each engineering school. These figures represent the sum of all students’ errors under each category as a percentage of all errors made under all four categories for each examination paper. These results highlight the students’ responses to the knowledge types emphasised in the examination papers. A consistent theme can be seen here where the proportion of errors made by students under the procedural knowledge categories were higher than the proportion of solution steps requiring procedural knowledge in each exam paper. Conceptual knowledge also appeared to be a problem for students, although to a lesser extent than procedural knowledge. Factual and rule knowledge were less problematic, as would be expected with less emphasis on these knowledge types in each of the papers.

Table 4.11 Proportion of student errors assigned to each knowledge category

Institution	*Factual*	*Procedural*	*Conceptual*	*Principle*
UOW	12.63%	45.07%	28.27%	14.03%
UTS	8.40%	63.95%	20.25%	7.41%
UTAS	10.24%	51.06%	24.59%	14.12%
AMC	12.53%	45.27%	28.24%	13.96%

Figures 4.9 to 4.12 illustrate the proportion of solution steps for each knowledge category in comparison to the proportion of errors made by students. These figures graphically compare the values from tables 4.10 and 4.11 for each institution. It is clear from these that the errors in procedural knowledge made by students are disproportionate to the number of opportunities (solution steps) they had to make these errors. This indicates that the procedural knowledge required in solving the exam questions at all four institutions was the most problematic for students.

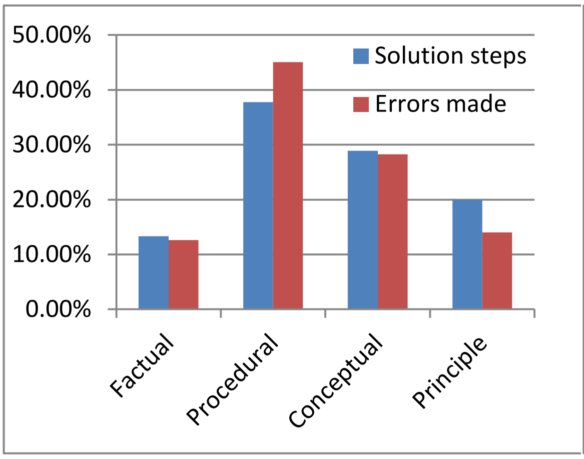


Figure 4.9 UOW error instances

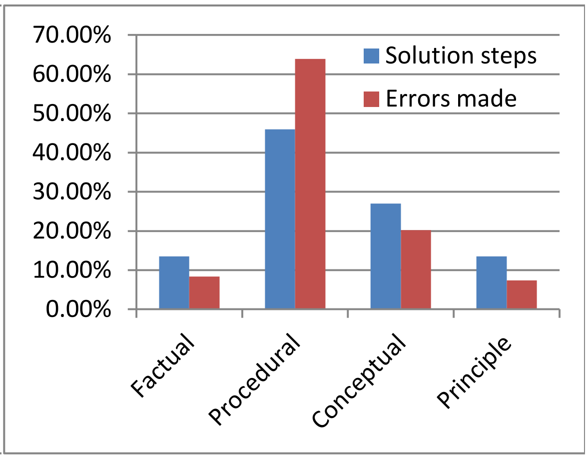


Figure 4.10 UTS error instances

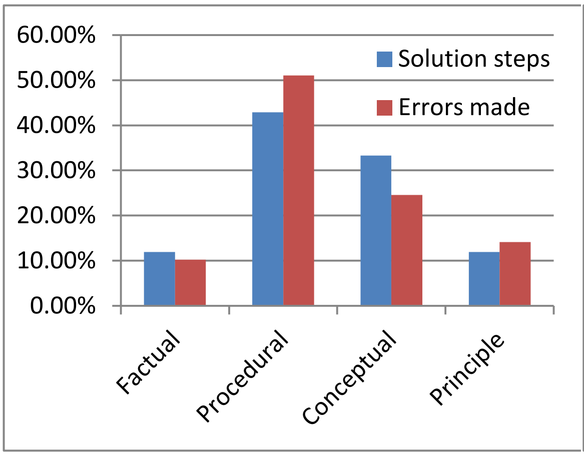


Figure 4.11 UTAS error instances

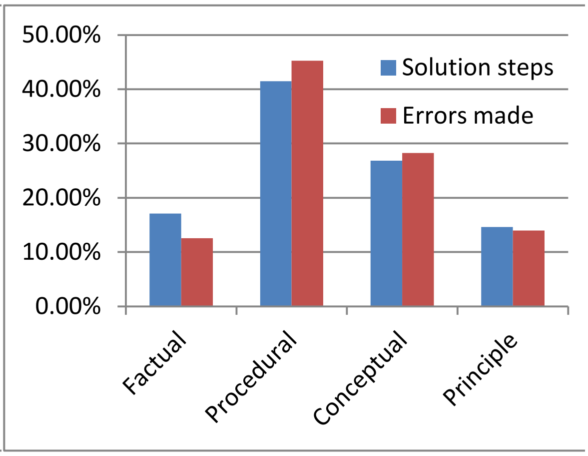


Figure 4.12 AMC error instances

4.3.2 Specific topics that challenge students

The full summary of common errors identified at each institution is included in appendix D. In brief, the specific topic areas and their associated knowledge types identified as most problematic are shown in table 4.12. Major problems were those that were encountered by more than 50% of the sample group of students. Table 4.12 demonstrates quite clearly that most of the major problems are evident in the procedural knowledge category. There are also a number of error types that occurred to a major extent at one institution, but to a lesser extent at another institution with a similar solution step. One such example, construction of bending moment diagrams, was a major problem at UOW and UTAS, but not so significant at UTS (the AMC paper did not include a Bending moment question). Similarly, maintaining sign conventions appeared to be problematic at AMC, but not at the other institutions.

The diversity of questions at UOW and UTAS was higher than UTS and AMC as the UOW and UTAS papers gave equal weighting to statics and dynamics type problems. The UTS paper was solely statics, and the AMC paper was largely dynamics. This was an important point to consider when reviewing the range of problem topics.

Overall, these results showed that there was little consistency in the concepts, facts, procedures, and principles of Mechanics that cause problems for students. In terms of the magnitude of the problem topics, the areas marked with ** in table 4.12 indicate where an area caused major challenges for students at one institution, but appeared to be less problematic in another where a similar content was assessed.

Table 4.12 Major problem areas in brief

Institution	*Factual*	*Procedural*	*Conceptual*	*Principle*
UOW		Applying vector dot product to find vector translation onto axis	Vector dot product and cross product	Direction of normal forces in curvilinear motion**
		Applying vector cross product to find vector translation about a point	Bending moments**	
		Bending moment diagrams**	Conservation of Energy	
		Calculating PE using correct values		
		Calculating impulse	Impulse	
		Oblique impact analysis		
UTS		Isolating free bodies **		Determining force vector direction**
		Method of sections**		
		Method of joints		
UTAS	Converting to and using rad/s for rotational velocity	Calculating 2nd moment of area for a composite shape	Relative acceleration	Force direction in cables (tension only)
	Units**	Finding centroids	Force couples	Force directions from pulleys
		Using polar coordinates to solve curvilinear motion problems	Power	
		Bending moment diagrams**		
		deriving distance from velocity and acceleration		
		Calculating power		
AMC	Sign conventions**	Applying equations of motion for spring mass damper system	Curvilinear motion**	
		Projectile motion analysis		
		Stress and strain in a cable		
		Shaft balancing		

**Instances where a similar step was in present in another exam paper, but did not present as a major problem for students.

4.4 Chapter Summary

In response to the sub-question *What are the key topic areas students have difficulty with?*, this component of the research split the investigation into two related components: The types of topics students had trouble with, in terms of the kinds of knowledge required for students to progress satisfactorily; and, the specific topics students struggled with (e.g. method of sections, or curvilinear motion). The results presented here are somewhat limited in the fact that the analysis of students' work, after an initial calibration process, was conducted and verified by only one researcher. It is possible that these results may have differed had the analysis been conducted by two or more researchers simultaneously and checked for inter-rater consistency. However, the overall outcomes of this research were consistent with other published work.

Many studies talked about Mechanics topics in terms of concepts (McCarthy & Goldfinch, 2010; Miller, Streveler, Nelson, Geist, & Olds, 2005; Streveler, et al., 2006; Streveler, et al., 2008). The examination paper and transcript analysis conducted here suggested that while the assessment of concepts did feature prominently, there was actually a strong assessment focus on procedural knowledge in Mechanics. This subsequently caused the majority of problems for students, supporting the direct relationship between presage and product identified by Biggs. In any case, as Linsey et al (2007) reported, students have suggested that this conceptual understanding does not help them to actually solve textbook type problems, which suggests that the focus on procedural knowledge is not limited to the examination papers used in this research.

Procedural knowledge is defined by Romiszowski as 'remembering' rather than 'understanding' (see 4.2.2). This study indicates that students' are required by the assessment to 'remember' more than they need to understand to pass the course. According to Ramsden, "If students perceive that their learning will be measured in terms of reproducing facts or implementing memorized procedures… they will adopt approaches that will prevent understanding from being reached" (Ramsden, 1992, p.182). The results of this analysis indicated that assessment practices were potentially driving students to take a surface approach to learning where memorisation of facts and procedures was prioritised by students. The assessment structure of the four Mechanics courses detailed in 3.2 confirmed that this type of assessment was not only limited to the final examinations. 20-30% of the course assessment, in addition to the 60-70%

weighting for the finals, was allocated to summative in-class quizzes similar in nature to the final exam. This meant that up to 90% of the assessment in a typical Mechanics course may in fact have been biased towards assessment of procedural knowledge.

In terms of specific topics, it was also apparent that problem areas can differ between institutions, with challenging topics presenting at one institution and not at another. In Chapter 2, the literature around engineering Mechanics education identified numerous topics and concepts described as being problematic for students. In Chapter 3 the comparison of these examination papers highlighted some common topics, but differing perceptions of difficulty amongst academics. The exam paper and transcript analysis demonstrated here that the topics and knowledge areas that challenged students were wide and varied. Moreover, the extent to which certain topic areas challenge students differed between institutions. From these results the problem topics in Mechanics appeared to be far from universal. This suggested that the challenging areas in engineering Mechanics may be more institution or even class specific. There was also the possibility that these problem topics are dependent on the way in which assessments are developed and administered.

These results were interesting in the context of Biggs 3P model. Biggs also highlights the relationship between how students approach learning (process) and the nature of the assessments and teaching context more generally (presage). The differences in learning outcomes between institutions seen here suggested that differences in teaching context were indeed translating to different learning outcomes. However, it was still not clear from the research to this point what effect ‘student factors’ have on learning outcomes.

Before it was possible to draw any definite conclusions about the differences in problem topics and students responses in exams, it was necessary to understand more about the impact of ‘student factors’ on learning outcomes in these Mechanics courses. More specifically, since students’ academic preparation is regularly cited as being related to their ability to perform in Mechanics (see 2.2.2), it was necessary to explore how students’ academic preparation related to their performance in Mechanics. An investigation of the relationship between students’ academic preparation and their performance in Mechanics is the focus of the next chapter.

Chapter 5
The relationship between students' academic background and performance in Mechanics

5.1 Introduction

The literature review in Chapter two identified several references to cause-and-effect type relationships between students' academic history and their ability to perform well in Mechanics courses. Mechanics in particular has a strong reliance on mathematical calculations to solve the types of questions that make up the majority of assessment. Dwight and Carew (2006) and Tyson (2011) suggested that students' high school academic history had a limited relationship to performance in key foundational subjects. In contrast, a key report on the future of engineering education in Australia, developed from consultation with engineering academics from around Australia, makes the very strong point that:

> Unless strong measures are taken within the school education system, top-achievers with high levels of mathematics may become a decreasing proportion of the commencing engineering student cohort, with long term negative impact on Australia's engineering capacity in research, innovation and industry leadership (King, 2008, p. 53).

This statement is significant in that this report represents comments and submissions from engineering deans and faculty from many different disciplines and universities. It is also in alignment with opinions among academic staff encountered by the author in day-to-day conversations. Clearly stakeholders believe that mathematics is crucial to learning in engineering degree programs overall. The prevalence of this view meant that, despite studies indicating the limited effects of academic history, a holistic exploration of Mechanics education at UOW, UTS, AMC and UTAS in this research would not be complete without exploring these issues.

The research covered in Chapters three and four indicates that there is limited consistency in student learning outcomes in this case study of four engineering Mechanics courses. This chapter explores whether the same can be said of student's academic preparation for the study of engineering Mechanics. The relationship between

academic preparation and assessed learning outcomes for the four engineering Mechanics subjects is the focus of the research in this chapter. This research was guided by the following sub-question:

What is the relationship between student's academic history and their achievement in Mechanics?

5.2 Method

The relationship between academic history and performance in Mechanics was investigated for a number of aspects of academic history. For the cohort of domestic high school leavers who enter university through traditional means, data was readily available for performance in high school subjects and their university entry score overall. For international students and those entering through alternative pathways, the analysis was limited to university subjects related to Mechanics at the University of Wollongong. These subjects were either run prior to the Mechanics course, or concurrently. Subjects investigated here for each of the participating institutions are listed in table 5.1.

Table 5.1 Academic history variable considered

UoW	***UTAS***	***UTS***	**AMC**
Entry ranking	Entry ranking	Entry ranking	Entry ranking
Math 2U*	Math Applications**		
Math EXT1*	Math Methods**		
Math EXT2*	Maths Specialised**		
Physics*	Physics**		
Chemistry*	Chemistry**		
Engineering Studies*			
Design and Technology*			
ENGG101***			
MATH141/142***			
MATH161***			
MATH187/188***			
MATH010***			

* NSW Higher School Certificate course
** TAS year 12 subject
*** UoW first year engineering subject

The statistical analysis here was limited to simple Pearson Correlations and t-tests run in the statistical analysis software package SPSS version 17.0 (IBM, 2010). A Pearson correlation describes the extent of the relationship between two continuous variables, in this case a student's entry ranking and their performance in Mechanics. The Pearson correlation coefficient r, ranges between -1 and +1. A correlation coefficient of +1 would indicate a perfect positive relationship between two continuous variables, i.e. higher entry rankings are related to higher scores in Mechanics. An r value of -1 indicates the opposite, i.e. that higher entry rankings are related to lower scores in Mechanics. The correlation coefficient r, provides an indication of two things, the direction of the relationship between two variables, and the strength of the relationship by how close it is to +/- 1. When performing this correlation in SPSS, the program also calculates the statistical significance of the r value, with standard cut off points of $p=0.05$ and $p=0.01$. The smaller the value of p is, the more statistically significant is the result. Muijs (2008) in his book on quantitative research in education suggests an interpretation of Pearson correlation coefficients:

- $r<|0.1|$ is a weak relationship;
- $r<|0.3|$ is a modest relationship;
- $r<|0.5|$ is a moderate relationship;
- $r<|0.8|$ is a strong relationship;
- and, values of $r\geq|0.8|$ are considered very strong.

The Pearson correlation assumes a linear relationship between variables. Based on views encountered by the author citing a quite straight forward association between academic history and performance, this linear relationship was appropriate for exploring these views. The Pearson correlation does not indicate cause. In analysing students' academic history in this way, it is only possible to discuss the relationship between factors, not cause-and-effect.

The other method used to explore the data was an independent samples t-test. This was also conducted with the aid of SPSS. The independent samples t-test compares the means for two populations. In this analysis, the two populations were determined as those students who had undertaken a particular course of study and those who had not.

The means were the students overall final mark in engineering Mechanics. These t-tests were conducted to determine whether having taken a particular subject in high school indicated a higher average mark in Mechanics among that population. As with the Pearson correlation, the t-test does not indicate cause and effect. The t-test as used here provided an indication as to whether students who had taken certain courses of study were more likely to pass Mechanics than students who had not.

Other student factors such as gender, socio-economic status, age, domestic or international enrolment, and other demographics were not considered in this analysis. Other authors have indicated that these factors may play a part in student engagement with university, including their persistence and retention, but have not related these to performance in the specific subject area of Mechanics (Baillie & Fitzgerald, 2000; Marra, et al., 2012; Vogt, 2008). As this research deals with measured learning outcomes in a specific subject area and not university engagement and retention more generally, it was deemed appropriate that these factors should not be considered in a statistical manner. They are considered qualitatively later in this thesis.

The use of student data for this component of the research was approved by the UoW Human Research Ethics Committee and ratified by the UTS and UTAS HREC's (AMC clearance is covered by the UTAS approval). Letters of approval and applications are included in appendix B.

5.2 Results

The analysis of high school outcomes and their relationship to performance in Mechanics was dependent on the data that could be retrieved from university records. Due to the availability of data for this study, the analyses focused on domestic high school leavers. This group forms the largest proportion of the class overall and the bulk of the student group failing Mechanics. The analysis covers the same engineering cohort at each institution that was used in the exam transcript analysis in the previous chapter.

5.2.1 University entry scores

The first area to be investigated was university entry scores. These scores are based on the NSW University Admissions Index (UAI, superseded in 2010 by the Academic Tertiary Admissions Ranking, or ATAR), and the Tasmanian Tertiary Entry Ranking, or TER. At UOW, the entry ranking held on record by the University is a number modified

from the students original UAI or TER based on bonus points awarded for enrolment in selected high school subjects deemed to be advantageous for studying engineering. As such, the scores used in the analysis for all four institutions will be referred to as entry rankings.

Entry ranking data was available for all students entering the university through traditional pathways as immediate, or recent school leavers. In some cases, students with entry rankings below the official cut off set by each university (ranging from 78-80) were granted entry under special conditions. At UOW, this situation usually involved participation in bridging courses before commencing the degree, and additional peer tuition in selected university courses. In other cases a student may have obtained an alternative qualification through another institution between leaving high school and entering university.

The Pearson Correlations between entry ranking and Mechanics mark or grade are presented graphically in Figures 5.1-5.4, and numerically with significance factors in table 5.2. The data available for UoW and UTS were actual scores in Mechanics, but only grades were available for UTAS and AMC. Grades are represented in Figures 5.2 and 5.4 from numbers 0-5 where: 0 = fail, 1 = technical fail, 2 = pass, 3 = credit, 4 = distinction, 5 = high distinction. These grades are typical of those used in Australian universities (UoW, 2012; UTAS, 2012; UTS, 2012).

The graphs show an approximately linear positive relationship between students' entry ranking and their performance in Mechanics at UOW and UTAS. The correlations also indicate these positive relationships are quite strong (Mujis, 2008) and statistically significant (see table 5.2). This aligns with the broad comparison of content and course structure in Chapter three where the UOW and UTAS programs were found to be the most similar. The data for UTS was far less distinct, with a general upward trend that is statistically significant, but modest. The AMC results were altogether different, with no discernible link between entry ranking and Mechanics grade.

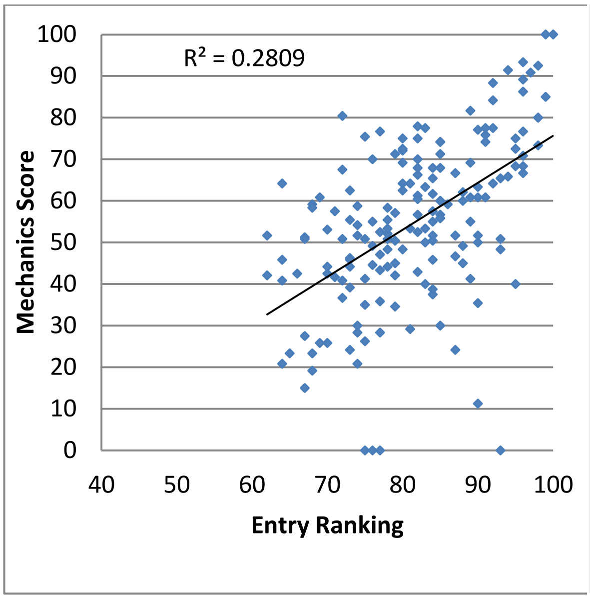


Figure 5.1 UOW Entry ranking vs. Score in engineering Mechanics

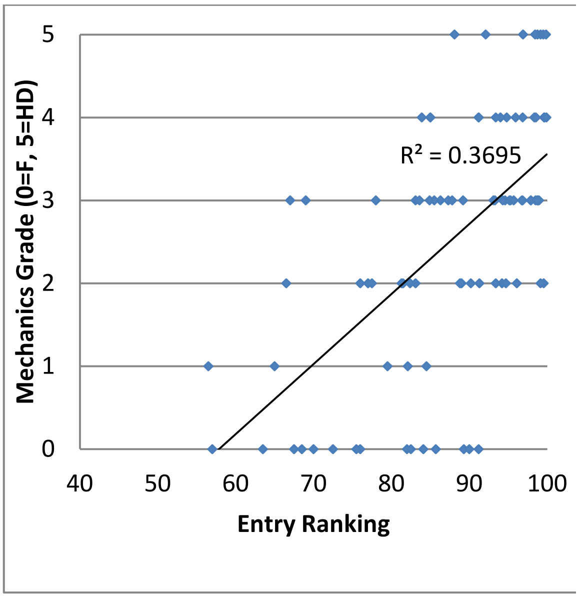


Figure 5.2 UTAS Entry ranking vs. Grade in engineering Mechanics

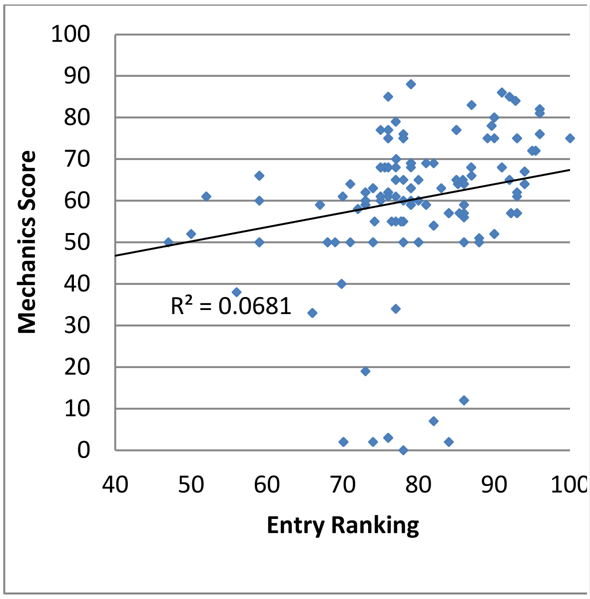


Figure 5.3 UTS Entry ranking vs. Score in engineering Mechanics

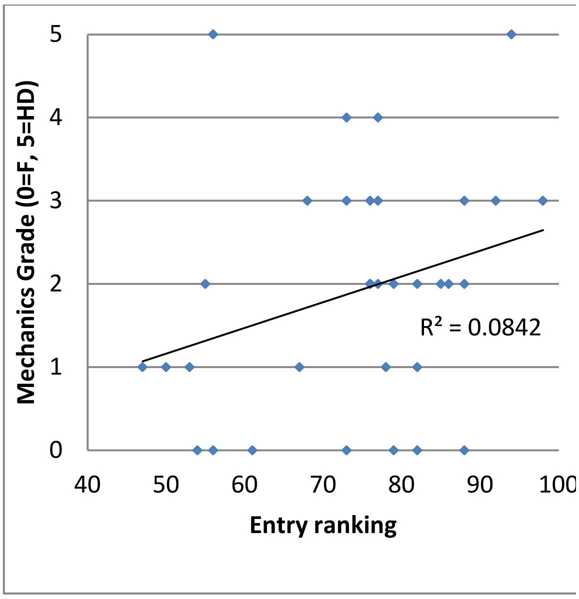


Figure 5.4 AMC Entry ranking vs. Grade in engineering Mechanics

Table 5.2 Correlation coefficients based on data presented in figures 5.2a-c

Institution	***UoW***	***UTAS***	***UTS***	***AMC***
Correlation	.532**	.608**	.261**	.290
Significance (2-tailed)	.000	.000	.000	.096
(n)	172	89	183	34

**statistically significant correlation (p=0.01)

As the key indicator for entry into the engineering degree program, the results for UTS and AMC in particular are surprising. This could be related to the makeup of the cohort because both UTS and AMC had larger numbers of students articulating through alternative pathways and subsequently have a higher proportion of students that hold low UAI's.

Taking a more digital approach (pass or fail), Figure 5.5 illustrates the data above in terms of the proportion of UOW students who actually failed Mechanics. This approach was explored in terms of entry rankings in Thomas, Henderson, and Goldfinch (2009, 2011). These publications were based on the research and data presented here and examined the impact of entry rankings using a 'risk factor' approach. This approach grouped students into entry score ranges and compared the number of students in each range passing and the number failing.

Figure 5.5 shows the percentage of each entry ranking range group failing the course on the left columns, and the percentage of the total cohort who failed ENGG152 from each range in the right column. This graph shows quite clearly that students coming in with lower entry rankings are at a higher risk of failing Mechanics. The second columns show though, that the largest volume of students failing Mechanics were in the 70-79 bracket (encompassing the 78 mark cut off for unconditional entry). While the students with a weaker academic background have higher fail rates, even in the 60-69 bracket, 61.1% of students were able to pass the course.

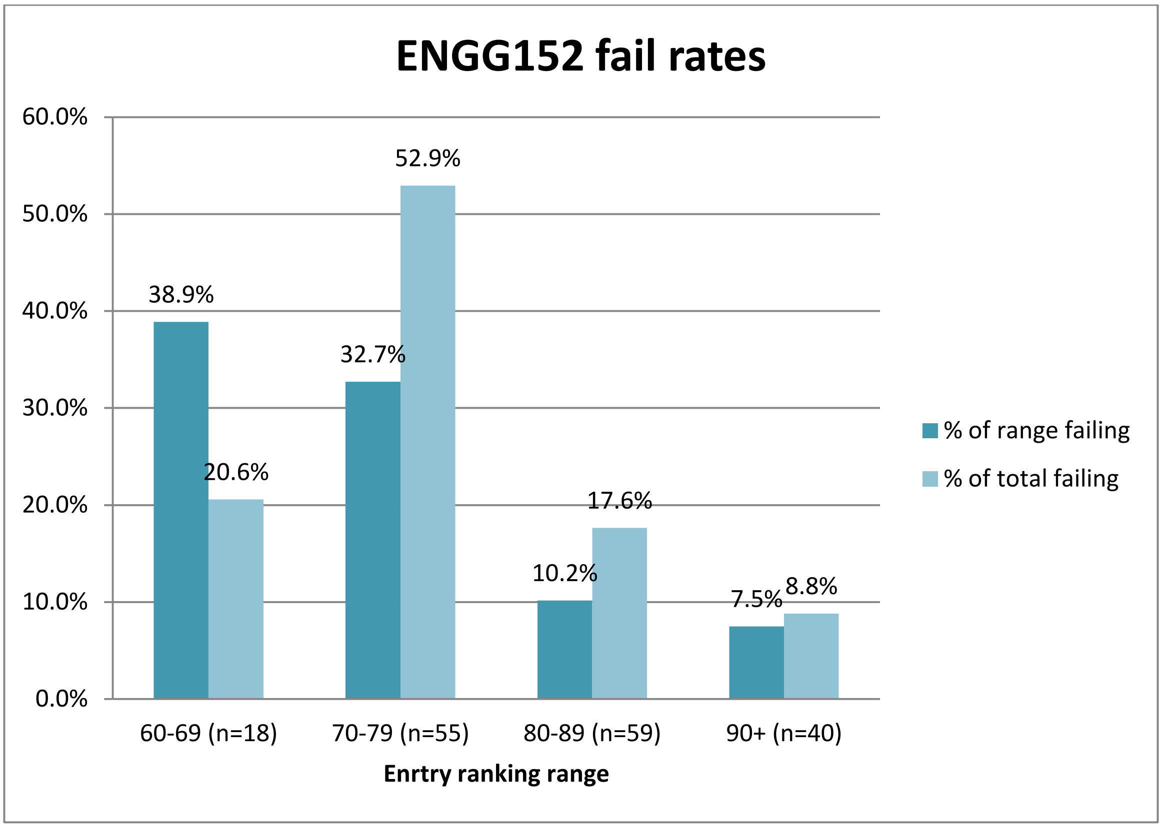


Figure 5.5 ENGG152 fail rates (2008) by entry rank group and by total cohort

The results were similar for the other three institutions where students with lower entry scores were at a higher risk of failing Mechanics. This analytical approach simply provided a different perspective on the makeup of the proportion of the cohort failing Mechanics, but it did not provide any further insight into the link between entry score and success in Mechanics. To explore their academic history further, students' performances in individual subjects were examined.

5.2.2 Mathematics

The next path of investigation was students' prior learning in mathematics. Here the analysis of data became challenging due to the nature of the information available from each institution. The data set obtained from UoW was the most complete and clear, and so forms the primary case study for sections 5.2.2 – 5.2.4. The UTAS data set included information only on which subjects students had taken in high school, no grades were recorded. The UTS dataset included information only on entry ranking and mathematics, however, the records did not distinguish which level of HSC mathematics students had taken. Therefore it was not possible to determine which HSC mathematics marks recorded in the UTS dataset were associated with which HSC mathematics

course. There was no information available to the author for academic history at AMC apart from entry ranking, so the data presented for the remainder of section 5.2.2 only represents UOW and UTAS.

Figure 5.6 shows graphically the correlation between students' scores in Mechanics at UOW and their performance in HSC mathematics subjects. The same data were also analysed using a Pearson correlation in table 5.3, with the inclusion of significance tests. The relationships between HSC mathematics courses and performance in Mechanics were all statistically significant, but varied in their magnitude. The correlation between the highest level HSC course, mathematics extension 2, was the strongest with a moderate-strong value of r = 0.612. This means that the 20 students out of 274 students in the 2007 cohort who had taken this maths subject may have enjoyed some advantage in Mechanics. The statistic is very similar, however, for students who had only taken standard mathematics, at r = 0.542. This suggests that the content of the different mathematics courses has a lesser significance than simply the students' performance in HSC maths. The intermediate course, mathematics extension 1, had a slightly weaker relationship to performance in Mechanics at r = 0.536. It is important to note that students who took standard mathematics may have also taken extension 1, and students who took extension 2 also took extension 1, so the student count did not add up to the total number of student who had a recorded mark in HSC maths (n=172).

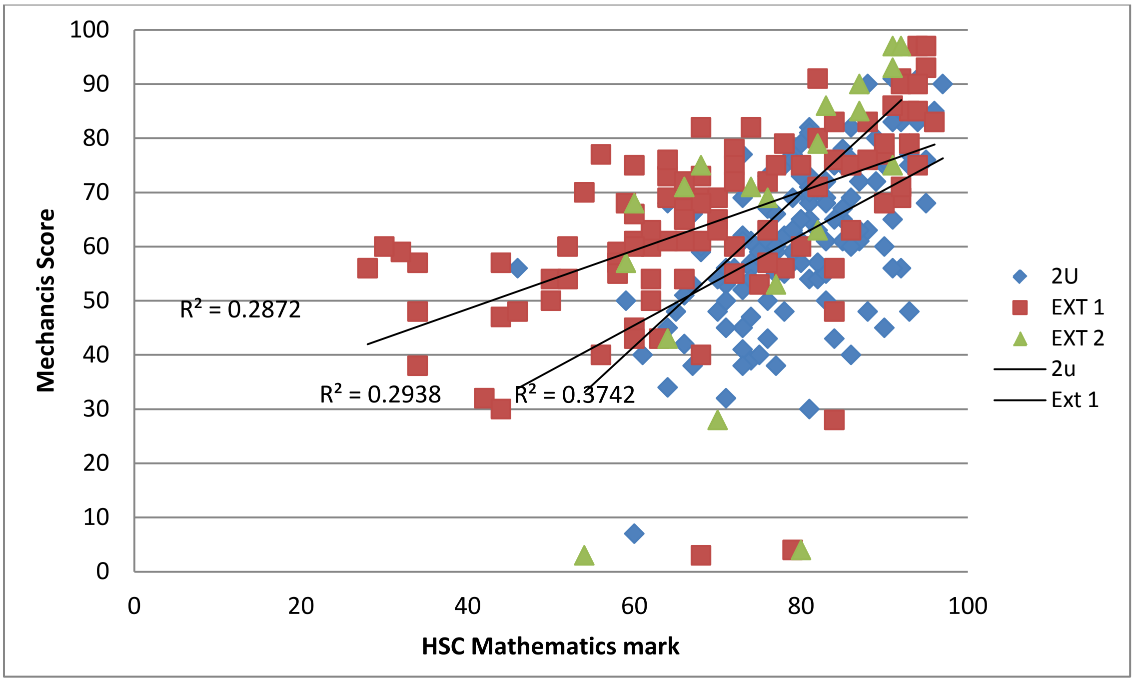


Figure 5.6 NSW HSC Mathematics performance against final Score in ENGG152 at UoW.

Table 5.3 NSW HSC Mathematics performance against final Score in ENGG152 at UoW using Pearson correlation.

Course	*Mathematics*	*Mathematics Ext 1*	*Mathematics Ext 2*
r value	0.542**	0.536**	0.612**
R^2 value	0.294	0.287	0.374
Significance	0.000	0.000	0.004
(n)	137	101	20

While the r-values imply that the variables are related in some way, they do not imply that higher maths scores ‘cause’ higher Mechanics grades (Kinnear & Gray, 2009, p. 399). The R^2 values associated with the trend lines shown in Figure 5.4 give a better indication of the effect of the size of the mathematics as it relates to Mechanics, but to further explore the relationship between students’ prior exposure to mathematics and their performance in first year Mechanics, students’ participation in different high school Mathematics courses was explored. Two sample T-tests compared the differences in means of a continuous variable for different groups. An independent samples t-test was performed in SPSS to compare students’ mean scores in Mechanics depending on what level of high school mathematics they had taken. Here the dataset was more complete, and both UTAS and UOW could be included in the analysis for comparison.

Table 5.4 presents the results for three different levels of Mathematics from the NSW HSC course for the UOW Mechanics course. In the second column of the table, ‘participation’, ‘Yes’ or ‘No’ values in this column indicate whether or not students had undertaken that particular HSC course. The third column ‘n’, shows the number of students represented in the sample. The fourth column shows the mean Mechanics mark achieved by students in each grouping. The last four columns contain important details of the t-test itself. ‘SD’ is the standard deviation for each sample, a measure of how spread out the sample was in terms of how far data points deviate from the overall mean. ‘t’ is the test statistic that determines whether the hypothesis is valid or not, and contributes to the determination of statistical significance. In this case the hypothesis for all t-tests was that participation in course X is related to HIGHER mean marks in Mechanics than non-participation. If $t > 0$ (positive) then this hypothesis is correct. If t <

0 (negative), it means the opposite is true, that participation in course X is related to LOWER mean marks in Mechanics than non-participation. ‘df’ is the degrees of freedom. In cases where equal variances between the two sample groups could be assumed, df is simply the sample minus 2. In cases where equal variances could not be assumed (usually due to small or unusual sample groups), the df was calculated separately by SPSS (UCLA, ,2013). The last column in the t-test tables shows the statistical significance of the test. Results with p-values less than 0.05 ($p<0.05$) are considered statistically significant and can potentially be related to populations beyond the test sample.

The data set does have some limitations resulting from the statistics available for the analysis. Data for their prior academic history was only available for students who commenced their degree through the standard entry pathway, directly from high school. Students recorded as not having undertaken maths may still have studied mathematics, but have entered as an international, interstate, or alternative pathway student. The data also does not capture the HSC results for students who are taking the ENGG152 course more than two years after commencing their degree. In total, 172 students out of the total enrolment of 274 are represented in this data set.

The t-tests here show the difference between students who undertook a higher level of maths, extension 1 or extension 2. The results here show a statistically significant advantage for students who took mathematics extension 1 in their HSC studies. No statistically significant difference was evident for students taking mathematics extension 2 in their Higher School Certificate or for the standard 2 unit mathematics. In the case of extension 2 mathematics, this may be a result of the small sample size, with only 20 of the 172 student sample having taken the highest level mathematics. None the less, this result was unexpected.

Table 5.4 Relationship between higher level mathematics participation for NSW high school leavers at UoW and performance in Mechanics.

	Participation	*n*	*Mean ENGG152*	*SD*	*t*	*df*	*p<0.05*
Math 2u	Yes	157	61.83%	16.24	1.769	170	0.079
	No	15	54.13%	14.56			
Math Ext 1	Yes	101	64.57%	17.00	3.392	170	0.001
	No	71	56.31%	13.73			
Math Ext 2	Yes	20	65.35%	27.55	0.756	20.33	0.458
	No	152	60.61%	14.12			

Next, the results of the student population who had recent NSW High school mathematics recorded were compared with the student group who have commenced through non-standard pathways or who had not undertaken HSC mathematics within the two years prior to this ENGG152 case study. These students were identified as those who did not have a recorded entry ranking in the dataset (n=102). These data are presented in table 5.5. This analysis shows a quite clear and statistically significant advantage for those students who have come to university through traditional pathways and have recently taken at least standard high school mathematics. Those who have not recently undertaken HSC mathematics also had a mean mark very close to the fail mark of <49%, indicating that this group may be a high risk one.

Table 5.5 Relationship between higher mathematics participation for NSW high school leavers at UoW and performance in Mechanics

	Participation	*n*	*Mean ENGG152*	*SD*	*t*	*df*	*p<0.05*
HSC mathematics	Yes	157	61.83%	16.24	4.351	221.40	0.000
	No	117	52.12%	19.66			

The data obtained from UTAS did not allow for a correlation to be developed as the records available only indicated which high school subjects that students undertook. In addition, the recorded mark in Mechanics, as seen in Figure 5.4, is only at the grade

level. The combination of nominal and ordinal variables here made correlations impossible and affected the reliability of the t-test because both of these methods relied on continuous variables to test significance. However, since the ordinal variable, in this case the students' grade from 0-5, is the summary of a continuous variable, it was still possible to treat it as a continuous variable with some caution. Therefore the t-test was used again here for comparability of results, although with the acknowledgement that the results were not as reliable as for the analysis of the UOW data.

Table 5.6 shows the results of the t-test for three levels of high school maths recorded in the UTAS data: Mathematics applications; mathematics methods; mathematics specialised. These three levels are broadly comparable to the NSW levels described earlier. The results here indicate that the only statistically significant (p=0.05) mean difference is in the participation in the highest level of high school maths, where students who took this subject enjoyed a higher level of success in Mechanics.

Table 5.6 Mechanics grade in relation to the level of maths taken in high school

	Participation	***n***	***Mean KNE112***	***SD***	***t***	***df***	***p<0.05***
Math application	Yes	11	2.09	1.70	-0.95	88	0.345
	No	79	2.56	1.50			
Math methods	Yes	24	2.13	1.62	-1.42	88	0.160
	No	66	2.64	1.47			
Math specialised	Yes	50	2.82	1.42	2.28	88	0.025
	No	40	2.10	1.57			

The data analysed above showed some relationship between prior learning in high school maths and Mechanics. Next, students' results in university mathematics and Mechanics were compared. This analysis involved data from UOW for four different university maths courses. MATH010 is taken by students in the semester prior to ENGG152 who have not studied mathematics recently or at all as preparation for subsequent mathematics courses. MATH141 and MATH187 were the standard mathematics courses taken by engineering students prior to ENGG152. MATH187 was generally taken by students who had a stronger background in mathematics prior to commencing university. The final course, MATH161, was equivalent to MATH141,

and run in the same semester as ENGG152. MATH161 was generally taken by students who had taken MATH010, or had failed either MATH141 or MATH187. The correlation between students' performance in these four subjects and their performance in ENGG152 is shown in Table 5.7. Students who completed ENGG152 who are not represented in this data set were most likely repeating the subject in the year this sample was taken or were studying part-time.

The results show no link between performance in MATH010 and MATH161 and performance in Mechanics. This may be a reflection of the demographics of students enrolled in these courses, being largely mature age students or students articulating through different pathways. As a result, this group are more likely to have varied abilities and backgrounds academically. There is a moderate to strong relationship between MATH141/187 and Mechanics that is statistically significant. The correlation is slightly stronger for MATH141 than for MATH187. This is also an unexpected result as enrolment in MATH187 requires a stronger background in mathematics than for MATH141.

Table 5.7 UoW Mathematics performance against final Score in ENGG152 using Pearson correlation.

Course	*MATH010*	*MATH141*	*MATH187*	*MATH161*
r value	0.142	0.672**	0.605**	0.284
Significance	0.677	0.000	0.000	0.169
(n)	11	82	83	25

5.2.3 Physics and related engineering subjects

Physics was another course considered due to the content carried over from these courses to engineering Mechanics. In particular, Newtons laws of motion and their applications are covered in high school physics. These concepts underpin the study of Mechanics. There was also data available for another subject closely related to engineering Mechanics, the NSW HSC course Engineering Studies. Engineering Studies contains a wealth of course content related directly to concepts, analytical methods, and contextual knowledge used in ENGG152.

At university level, one UOW subject also included in this analysis is ENGG101 (Foundations of engineering). This course was taken by most students in the session prior to ENGG152 and includes extensive study in basic Mechanics which is directly related to ENGG152. The data used for this subject was only for the 2007 year, which means it excluded most of the students who are repeating ENGG152 and left the data as a sample representative of students taking Mechanics for the first time. Table 5.8 shows the Pearson correlations between HSC Physics, HSC Engineering Studies, ENGG101, and ENGG152. Both of these HSC subjects had moderate-strong correlations to performance in Engineering Mechanics. ENGG101 also had a similar moderate-strong correlation to ENGG152. All of these results are similar to the correlations shown for other HSC and University results above.

Table 5.8 HSC Physics and Engineering Studies performance against final Score in ENGG152 using Pearson correlation

Course	*HSC Physics*	*HSC Engineering Studies*	*ENGG101*
r value	0.601**	0.633**	0.661**
Significance	0.000	0.000	0.000
(n)	144	54	202

Table 5.9 examines the relationship between these HSC subjects and Mechanics using t-tests. T-tests were not conducted for ENGG101 as all students are required to take this subject. The results of this test were more clear cut than those reported for mathematics subjects in table 5.4. Here we can see that there is a statistically significant advantage present for students who had taken high school physics or engineering studies. This suggested that those high school subjects with a direct content overlap with Mechanics were beneficial to students.

Table 5.9 Relationship between higher mathematics participation for NSW high school leavers at UOW and performance in Mechanics

	Participation	*n*	*Mean ENGG152*	*SD*	*t*	*df*	*p<0.05*
Physics	Yes	144	62.83%	15.34	5.022	242.31	0.000
	No	130	51.99%	19.82			
Engineering studies	Yes	54	62.93%	14.20	2.356	272	0.019
	No	220	56.40%	19.09			

Table 5.10 shows the results of the t-test for students who took high school physics prior to Mechanics at UTAS. Again we see a strong advantage for those who took physics. However, this result is limited by the sample size, which includes only 10 students who did not take physics.

Table 5.10 Relationship between higher mathematics participation for TAS high school leavers at UTAS and performance in Mechanics

	Participation	*n*	*Mean KNE112*	*SD*	*t*	*df*	*p<0.05*
Physics	Yes	80	2.64	1.49	2.492	88	0.015
	No	10	1.4	1.43			

5.2.4 Unrelated subjects

As discussed in 5.2, these statistical tests describe the relationship between two variables, but do not indicate cause-and-effect. To further explore the significance of the relationships between prior learning and performance in Mechanics, students' performance in high school subjects unrelated to Mechanics was examined. Table 5.11 considers the correlations between four subjects not directly related to engineering Mechanics. HSC chemistry is similar in its conceptual and analytical nature, however, the content and concepts are unrelated to first year Mechanics. HSC Design and Technology could have some advantage in that students who took this course may be more familiar with the behaviour of structures and mechanisms and real world applications of engineering principles, but again, the mathematical content and concepts involved are largely unrelated. MATH142 and MATH188 are university subjects which

follow on from MATH141 and MATH187 respectively. The content of these subjects is not directly related to the mathematics required for ENGG152 and they are taken concurrently with ENGG152. HSC Chemistry and MATH142 both exhibited similar correlations to performance in Mechanics to more directly related subjects, in particular, ENGG101. Interestingly, MATH188 had the strongest relationship to performance in Mechanics of any other subject presented here, despite the content not being directly applicable to Mechanics. Design and Technology had a moderate, but less statistically significant correlation to Mechanics.

Table 5.11 Performance in unrelated subjects against final Score in ENGG152 using Pearson correlation

Course	*HSC Chemistry*	*HSC Design and Technology*	*MATH142*	*MATH188*
r value	0.617**	0.475*	0.684**	0.865**
Significance	0.000	0.016	0.000	0.000
(n)	88	25	77	75

The results of t-tests for these two unrelated HSC subjects are shown in table 5.12. Here it can be seen that the advantage for students who took Design and Technology was not statistically significant. For chemistry, by contrast, there is a statistically significant advantage of nearly 7% mean difference for students who took this course compared to those who didn't. This result is comparable to HSC Physics (~11%), Engineering studies (~6.5%), and Mathematics extension 1 (~8%).

Table 5.12 Performance in unrelated subjects for NSW high school leavers at UOW and performance in Mechanics

	Participation	*n*	*Mean ENGG152*	*SD*	*t*	*df*	*p<0.05*
Chemistry	Yes	88	62.40	16.65	2.958	272	0.003
	No	186	55.46	18.79			
Design and Technology	Yes	25	61.16	16.36	0.991	272	0.323
	No	249	57.34	18.57			

Table 5.13 shows the results of a t-test for UTAS Mechanics students who had taken Chemistry in high school. Again the statistically significant result showing an approximately 0.9 grade point mean difference advantage for students who had taken Mechanics is comparable to that of physics (1.24gp), and Mathematics specialised (0.72gp).

Table 5.13 Relationship between high school chemistry for TAS high school leavers at UTAS and performance in Mechanics

	Participation	*n*	*Mean KNE112*	*SD*	*t*	*df*	*p<0.05*
Chemistry	Yes	66	2.74	1.47	2.582	88	0.011
	No	24	1.83	1.49			

5.2.5 Summary of results

This chapter has presented a simple evaluation of the relationships between academic history and performance in Mechanics. Table 5.14 presents a summary of the findings of the analyses. It is clear from the results for UOW and UTAS that a moderate-to-strong relationship exists between academic performance in Mechanics and academic performance in other courses of study.

A key finding from this work is the similarity in correlations for numerous subjects in the UOW sample, and in the t-test results for UOW and UTAS. These correlations and mean differences are apparent regardless of whether courses of study are directly related to the content of the engineering Mechanics course or not. This suggests that students' performance in other subjects is indicative of their likely performance in Mechanics, but that conclusions cannot be drawn as to the advantage of particular courses of prior. That is to say, top performing students will tend to remain high performing students, average students will tend to remain average students, and so on. It can be seen that performance or indication of participation in some courses have stronger links than others, however, with the exception of MATH188 at UoW, none indicate more than a moderate to strong relationship to performance in Mechanics.

Intriguingly, it is MATH188 and the alternative mathematics, MATH142, that have the strongest correlations to performance in Mechanics. These two subjects are not directly

related to ENGG152, but do run concurrently with ENGG152. This reinforces the indication from other subjects that these correlations explain only that students performing well in other studies are likely to also perform well in Mechanics.

In the case of UTS and AMC, the results from the data available present a less clear picture. From the data available, the poor correlation between entry scores and performance in Mechanics may be a result of a more diverse student enrolment than those of UOW and UTAS. Further exploration of this outcome was limited by the range of data available from UTS and AMC for this research.

Table 5.14 Summary of results from examining the relationship between courses taken by students prior to studying Mechanics, and Mechanics.

	Course	*Statistically significant link?*	*Comment*
UoW	Entry score	Yes*	Moderate to strong correlation
	HSC maths standard	Yes***	Moderate-strong correlation and advantage from participation
	HSC maths ext 1	Yes***	Moderate-strong correlation and advantage from participation
	HSC maths ext2	Yes**	Moderate
	University Maths	Yes*	Strong and very strong correlations, particularly for concurrent MATH subjects
	HSC physics	Yes***	Moderate-strong correlation and advantage from participation
	HSC eng studies	Yes***	Moderate-strong correlation and advantage from participation
	HSC Chemistry	Yes***	Moderate-strong correlation and advantage from participation
	HSC Design & Technology	Yes*	Moderate correlation only
UTAS	Entry score	Yes*	Moderate to strong correlation
	Math application	No**	
	Math methods	No**	
	Math specialised	Yes**	Modest advantage, significant at p=0.1 level
	Physics	Yes**	Strong advantage, result limited by sample diversity
UTS	Entry score	Yes*	Modest correlation
AMC	Entry score	No*	

*Pearson correlation
**T-test
***Pearson correlation and t-test

5.3 Chapter Summary

The research described in this chapter explored elements of the 'Student Factors' component of Biggs' 3P model. It was possible to delve deeper into the statistical analysis and develop multi-variable models of academic history and its relationship to performance in Mechanics. Different statistical tests could also have been used to explore the relationship between variables in more depth, and with more certainty. When considering the direction this component of the research should take, a great deal of thought was given to how far to go, and how useful it would be. This raised some important, practical issues.

Firstly, in developing more complex representations of students' academic histories and their relationship to Mechanics performance, the proportion of the cohort represented in any model would inevitably decline. The resulting models of academic history to Mechanics performance that only describe a small number of students in the course may not be useful. This effect could already be seen in some of the basic statistical analyses here where numbers were small in relation to the whole class. There exists another very practical issue around the implications of these results, and determining which course of action could be taken in response to them. At the time of writing there are increasing pressures at the federal government level to increase participation in higher education nationally, especially in science, technology, engineering, and mathematics (STEM) fields (Bradley, Noonan, Nugent, & Scales, 2008; DIISRTE, 2009). The sector is moving towards a student support focus, as opposed to restricting entry based exclusively on academic performance.

Secondly, there is a limit as to how many variables can be controlled for, or explained by any one model. Consider the case of students who took physics in high school. The content of high school physics that relates to Mechanics is only one component of an extensive course (BoS, 2002), so it is possible for a student who has performed at credit level to have little understanding of Newtonian physics. The overall marks in courses that were available did not allow the researcher to control for specific course content. Similarities in the results for HSC Chemistry and HSC Physics for UOW students appeared to indicate that the specific High School course content is, in the end, unimportant in indicating likely Mechanics performance. This finding aligns with those

of other researchers, who have found that the most consistent indicator of performance is prior performance in any other courses of study (Balascio, et al., 2007).

Biggs' suggests that both prior knowledge and academic ability are important student factors in the presage stage. The analyses carried out here indicate that students with a history of higher academic performance are more likely to succeed in Mechanics. That is, their academic ability appears to be more critical than prior knowledge. However, it also tells us that students with lower performing backgrounds are still capable of succeeding in Mechanics, and a majority do so. This indicates that there are additional complexities around 'student factors', possibly beyond academic ability, prior knowledge and motivation as highlighted in Biggs, 3P model.

In response to the sub-question leading into this chapter, "Does students' academic history coming into the Mechanics course have an effect on measured learning outcomes?", the answer is yes. However, the analysis conducted here only indicates that students' academic performance in general prior to commencing Mechanics is a likely indicator of their performance in Mechanics. It cannot be concluded that there is any specific subject area (mathematics, physics, chemistry, etc.) relationship between prior study and the Mechanics area.

In addition to an exploration of the Mechanics course structure and the teaching context (Chapter 3), assessment (Chapter 4) and the academic history in this chapter, more still needed to be understood about the student factors, the teaching context, and crucially, the 'process' dimension of the 3P model. Chapter 6 explores these elements through a qualitative exploration of current students' and academics' perceptions of Mechanics education.

Chapter 6
Students' and Educators' views on Engineering Mechanics Education

6.1 Introduction

Chapter two reviewed the literature surrounding engineering Mechanics education. This review discovered a wide range of opinions, hypotheses, and research findings regarding the high fail rates in these subjects that were in fact, embedded in a range of educational contexts and systems around the world. The research outlined in Chapters three, four, and five focussed on the context of four Australian engineering schools and concluded that:

- The teaching and assessment practices in difference Mechanics courses were broadly similar;
- there was a strong emphasis on short calculation/problem type questions in assessment.
- there was a bias towards assessing procedural knowledge over conceptual knowledge;
- concepts and procedures that were problematic for students varied between institutions; and,
- students' academic background is an indicator of their likely success in Mechanics, but the nature of this relationship in terms of subject content is not clear.

These findings provided some insight into the high failure rates in Mechanics, suggesting that the methods of assessment used in Mechanics were a key contributing factor. However, these findings were limited in their explanation of how students and academics engage with Mechanics education. Student engagement has been a significant area of study and motivator for those seeking to improve learning in Mechanics (see 2.2.1 & 2.3). Relating the findings of other studies to issues identified in the preceding chapters was problematic, since the ways in which students and staff both

engage with the learning experience are inherently context dependent (Skinner & Belmont, 1993). It was deemed necessary to explore the views and perceptions of academics and students from the same Mechanics courses that data had been drawn from to this point. Given the similarities in delivery modes, assessment format, and content overlap between the four Mechanics courses, only one university, UOW, was used as the case study for this work. Focussing this work was the sub-question:

What are the views of students and academics on first year engineering Mechanics education?

6.1.1 Chapter Roadmap

The richness of the data used in this component of the research resulted in a lengthy and detailed analysis. Hence, reporting the results here is rather complex. To simplify the navigation of this particular chapter, the steps below provide a simple guide for the reader.

1. Section 6.3 provides an overview of how the data was collected and analysed. The data was analysed using two different methods.

2. Section 6.3 describes the outcomes of the first data analysis method: An holistic approach which provided a simple summary of participant responses. Quotes are used to support the researchers interpretation of participant responses overall. Interim findings are reported at the end of this section.

3. Section 6.4 describes the outcomes of the second data analysis method: A detailed qualitative analysis that separated each participant comment into themes. This approach minimised the impact of any researcher bias. Participant responses were analysed in terms of themes, with quotes used to support a detailed exploration of each theme.

4. Section 6.4 summarises the key findings of the study. Major themes are discussed in more detail and related back to Biggs 3P model. Table 6.4 in this section may be a useful tool for the reader to refer to while reading through section 6.4 where all key points are summarised.

6.2 Method

Exploring the views and opinions held by students and academics involved in engineering Mechanics learning and teaching could have been done in several ways. Designing a method for this research was considered from two different angles. A structured-quantitative approach, as described by Fink (2003), where themes identified from the literature review were used to define a framework of questions for participants to generate simple research data using either interviews or a paper based survey. This approach has been used in other studies in engineering education with both paper based surveys (Goldfinch & Layton, 2011; Nghiem, Goldfinch, & Bell, 2010) and focus groups (Pomales-Garcia & Liu, 2007). Paper based surveys are also standard practice for many teaching quality evaluations, including UOW's Teacher Evaluation Surveys and Subject Evaluation Surveys (Wollongong, 2012a, 2012b). The quantitative survey approach is effective in developing large datasets on very specific questions (Borrego, Froyd, & Hall, 2010). However, questionnaires and highly structured interviews are limited in their effectiveness in identifying and exploring new themes not considered during the creation of the question set (Bouma, 2000). In this instance the approach would have limited the research to a set of issues the researcher already understood to be problematic in engineering Mechanics education. It was also important to consider that as a graduate of the mechanical engineering degree program at UOW, the author has his own opinions on Mechanics education from personal experience, so regardless of the care taken these opinions would influence the focus of questionnaires or interview questions.

To move beyond what has previously been investigated in Mechanics education, a more open ended research method was identified and applied. A semi-structured qualitative approach where themes from the literature review were used to form a basic framework for participant questioning, would allow more flexibility in terms of participant responses and secondary questioning (Kvale, 1996, p. 124; 2007, p. 57). This method has been used effectively by other researchers in engineering education in a variety contexts to generate new understandings on how students and others perceive a learning experience (Besterfield-Sacre, Atman, & Shuman, 1998; Chan, 2012; VanderSteen, Hall, & Baillie, 2010).

The qualitative research approach using semi-structured interviews or focus groups is limited in its ability to yield data suitable for statistical analysis, and the results normally cannot be generalised to the wider population (Besterfield-Sacre, et al., 1998). However, on balance, the semi structured qualitative method is better suited to identifying new ideas in a complex area than quantitative surveys. Hence, this approach was used to explore students and educators views on Mechanics education.

The method used in this study involved two major components: Focus groups held with current students of the first year Mechanics course at the UOW, ENGG152; and, one-on-one interviews with academics who taught or tutored ENGG152 at the University of Wollongong. All the research described in this chapter was approved by the UoW Human Research Ethics Committee in 2008 under approval number HE08/240 (see appendix E letter of approval, participant information sheet, and consent form).

6.2.1 Focus Group design

Focus groups, using a semi-structured questioning framework, were identified as the preferred method for exploring students' views on Mechanics education. There were a number of important considerations which supported the use of focus groups over interviews. Foremost of these was the position of the students within the context of the university. Student participants were asked to discuss issues they felt were affecting their education positively and negatively, which almost always involved commenting on educators and the university itself. Here there was potential for the focus group facilitator, in this case the author, to be seen as an authority figure, as an employee or representative of the university. Focus groups allow for the interaction between participants, creating the space for participants to discuss and debate issues that were important to them without undue influence from the moderator (Kamberelis & Dimitriadis, 2005; Morgan, 1988). In this situation focus groups position the researcher as a minority within a group of participants, effectively decentring the role of the researcher and allowing the participants more opportunity to take the lead in discussion (Kamberelis & Dimitriadis, 2005). Decentring the facilitator may also promote a strength-in-numbers mentality among participants, particularly if they are previously known to each other. It was anticipated that this would create a more open atmosphere for comment on otherwise sensitive issues.

Secondly, focus groups allow a great degree of freedom in terms of which issues are discussed and what points are raised. In this case the focus groups were conducted with a low to medium level of moderator involvement (Morgan, 1988, pp. 48-52). This meant that participants were provided with a set of prompt questions which were developed to guide the discussions through a set of broad themes identified in the literature review. However, the duration of discussion around these themes was mediated by the participants. Table 6.1 describes the prompt questions in the order they were used, with a brief outline of their intention and derivation.

Table 6.1 Student focus group prompts

Prompt	***Purpose and derivation***
What don't you like about any aspect of the course? Exams, lectures, tutorials, labs, staff etc.	To start participants off with a critical mindset and show them that the research seeks their opinion whether it is positive or not. This also aims to establish common ground between the students. The question also starts the session with a focus on the course, content, assessments and so on rather than the participants themselves to avoid intimidating participants in a not yet familiar setting.
What do you like about the course?	To identify positive aspects to encourage diversity of responses for the rest of the session.
Is there anything you would like done differently from your experience so far?	To establish the importance of participants' opinions and empower their comments by flagging that that change is possible. The first three questions are very broad and open ended, and do not draw from particular themes. These questions allow the group dynamic to establish itself.
Are there any particular topics you find more difficult than others?	To find what topics participants' perceive as most or least difficult, and whether these are uniform within and between groups. This is the first question to pick up on themes from the literature review (see 2.2.4), focusing on challenges posed by content.
Do you prefer lectures/tutes/labs as a teaching mode? Why?	To establish students learning context preferences from the range currently offered in the Mechanics courses. This question was followed by guided discussion on what other learning modes would be useful. This draws on the theme of pedagogy and learning resources in Mechanics

	(referring to 2.3).
How much study time to you think is fair for a course like this? Would you do this amount regularly?	To explore students study habits and work input. This question is derived from the commonly cited issue of students commitment to their studies and time spent on task (see 2.2.1
Are there any factors other than the course itself that you think might make study harder?	To explore outside influences that may affect academic success. This is another area commonly referenced in the literature and includes, social, family and work commitments outside the university (see 2.2.1).
How do you think subjects/education you took before ENGG152 have affected your learning?	To collect participants' beliefs on impact of academic history on success in Mechanics. This draws from commonly stated beliefs that students are ill prepared for studying Mechanics (see 2.2.2).
How do you think you will go in the subject overall? Would you be happy with this?	To explore participants' standards and expectations with respect to their overall performance in Mechanics. Responses to this question may offer some insight into responses to earlier points of discussion.

The prompts used in the focus groups were very general and served only to guide the discussion to cover a broad range of issues in keeping with the semi-structured approach. Prompts also had a deliberately broad focus to give participants freedom to express what was at the forefront of their educational experience without the need to answer a specific question.

6.2.2 Interview Design

Developing an approach for collecting the views and opinions of the academics responsible for teaching engineering Mechanics posed different challenges to the student focused research. The availability of staff to participate in interviews was less flexible than the students, and would be dictated in this case by the participants themselves. Unlike student groups, the authors experience has been that conflicting opinions and status in the workplace (experience, seniority, hierarchy, etc.) can affect the dynamic of a focus groups discussion. It was felt that there was a risk of power imbalances hindering participants' real or perceived freedom to contribute their opinion. The effective use of frameworks to anticipate such group dynamics can help the facilitator to manage these issues in focus groups (Dreachslin, 1998). However, the

researcher was not well prepared to anticipate group dynamics, due to insufficient familiarity with this particular participant group. In addition, the way the focus group reduced the influence of the researcher to improve participant interaction could have had a negative effect with academic staff as the participants. As a student, the author felt that maintaining focus and ensuring contribution from all participants would be difficult in this setting, and that dominant participants could take over. These complexities ruled out focus groups as an appropriate method of collecting data from academic staff. The same constraints already outlined in 6.2.1 with respect to paper based or online questionnaires also remained.

Semi-structured, one-on-one interviews as described by Kvale (2007) were seen as the most appropriate method of surveying academics' views on why students struggle with introductory Mechanics. One-on-one interviews offered flexibility in terms of scheduling and eliminated the complexities of real or perceived power imbalances between participants (Kvale, 2007, p. 14). Among the participants were past, present, and future coordinators of the first year Mechanics subject at UOW, ENGG152, junior and senior academics, and a wide range of cultural and educational backgrounds. The one-to-one situation allowed each participant ample time and opportunity to express and justify their views. This was important, given the breadth of experience of some engineering academics.

The interview research approach, as with focus groups, is well suited to gathering rich qualitative data as it allows freedom for deeper investigation of issues raised through follow up questioning (Bouma, 2000, p. 180). A deeper investigation may be necessary when contradictory statements are made, or strong views are expressed without justification. An audio recording was taken during each interview to allow transcription after the interview for subsequent analysis.

Questions and prompts for the interviews were almost identical to those used in the focus groups, though posed in a different order (see table 6.2). In this case the prompts were rearranged to focus first on the behaviour of students in the course for the same reason the focus was initially placed on the curriculum for student participants. The rearrangement of questions delayed placing the interviewee in a position where their work may be brought into question until they had become more comfortable with the interview setting.

Table 6.2 Academic interview prompts

Prompt	***Description and Derivation***
What do you students appear to like most about the course?	To start participants off with a critical mindset and show them that the research is focused on student learning, the positives and the negatives. The question also starts the session with a focus on the course, content, assessments and so on rather than the participants themselves to avoid intimidating participants in a not yet familiar setting.
Are there any particular aspects that student seem to dislike about engineering Mechanics (more than usual)?	Focus on the opposite issues to the first question.
Which topics do students seem to find more difficult than others?	To explore the subject at the topic level, again focusing on student learning.
What sorts of things have been tried to improve learning in Mechanics? What was the rationale?	Explore participants knowledge of alternative approaches to teaching or things they have tired in the past. The counterpart to the question for students on what they would like done differently.
What teaching modes do students appear to prefer? Why might this be?	To establish academics views on students learning context preferences from the range currently offered in the Mechanics courses. This question was followed by guided discussion on what other learning modes would be useful. This draws on the theme of pedagogy and learning resources in Mechanics.
What impact do you think academic history has on learning? Which aspects in particular?	To collect participants' beliefs on impact of academic history on success in Mechanics. This draws from commonly stated beliefs that students are ill prepared for studying Mechanics.
How much study time to you think is fair for a course like this? Do you think students do this amount regularly?	To explore academics ideas on students study habits and work input. This question is derived from the commonly cited issue of students commitment to their studies and time spent on task.
Have you ever had complaints from students	Counterpart to the student question on how they think they will perform in the course. Also seeks what

that the subject is too hard/easy?	feedback academics have had on the course, usually through follow up questioning.
Are there any factors other than the course itself that you think might have a negative effect on learning?	To explore outside influences that may affect academic success. This is another area commonly referenced in the literature and includes, social, family and work commitments outside the university.

6.2.3 Implementation

The focus group research design had to take into account the context in which the research would be conducted. Participants were drawn from the large first year Mechanics subject ENGG152 at the University of Wollongong, which had an enrolment of approximately 313 students during the 2008 Spring Semester when the focus groups were run. In this session the overall fail rate was 29%, which was slightly higher than in previous years. There were a number of changes to the subject in 2008 from the 2007 academic year that was the focus of Chapters three, four and five. This included two new lecturers; one experienced, one a new member of staff who was provided with lectures that had been developed by an experience lecturer who taught the subject in 2008. The content, structure, delivery modes, and assessment practices remained unchanged between 2007 and 2008. These were described in detail in Chapter 3. Due to the quantity of data collected from the UOW participants, and financial constraints at this stage of the research, no participants were drawn from UTS, UTAS or AMC.

Calls for participation in the student focus groups were made in lectures and via the student messaging system in SOLS (Student Online Services). No follow up correspondence or personal invitations were made in accordance with the conditions of ethics approval for the research. As an incentive to encourage students to volunteer, participants were put into a draw to win one of three personal music players (iPod Shuffles). The broad announcement of the focus groups did not appear to strike a chord with many students, nor did the incentive provided, so the response rate at UOW was low. Using this approach only 11 students signed up and attended a focus group session. This number was lower than expected. There was no other research involving students conducted in the subject prior to the call for participation in this research. However, the cohort were likely to have completed a number of subject evaluation surveys and teacher evaluation surveys in other subjects prior to this research, and received numerous requests for feedback from the institution in previous years. Care is needed

when considering the most appropriate strategy for recruiting participants (Barbour, 2007, pp. 52-55). In this instance a financial incentive, by way of a prize may not have been ideal, so given the nature of the research it may have been more effective to offer additional tutoring help. This approach was used in further qualitative research described in Chapter 7. It is not known, however, whether competing requests for student feedback were a factor in the low participation rate seen here.

Participants in the focus groups held at UOW were self- selecting, and although these types of groups can limit the diversity of research participants, in this instance it appeared to work well. The self-selecting participants in this research resulted in groups of participants that appeared to be fairly homogenous in terms of their path to university, and economic and social background. In several of the focus group sessions the participants were also known to each other (friends in some cases). The shared experiences and backgrounds of participants in these groups may have enabled deeper discussion of the issues raised during discussion (Kamberelis & Dimitriadis, 2005). In a several instances, participants were able to talk though issues in great detail without intervention from the facilitator. The self selection by chance also resulted in a varied cross section of students in terms of self reported academic ability. The disadvantage of the self selection of participants was that international students were unrepresented and mature age students were under represented. The participants may have also expressed interest in the focus groups due to an unfavourable experience with the Mechanics course, although the reverse was also possible.

Groups were limited to seven participants, plus the facilitator to allow all participants ample opportunity to respond in the one hour time allotted. With participation rates as they were, three focus groups were run with three participants and one with two participants. Participants were asked to stay for at least 40 minutes of the one hour allotted. It was evident that these time targets were appropriate, though some groups ran slightly longer that 1 hour at the request of the participants.

Interviews with academics responsible for teaching engineering Mechanics were held with academics from UOW who were involved with the first year Mechanics subject ENGG152, either in 2008, or within recent years. Participants were full time teaching-research staff with coordination, lecturing, or tutoring experience in ENGG152. Academic staff were invited to participate via email or in person and of the ten staff

contacted, eight volunteered to participate. Eight interviews were conducted, though one was excluded from the research due to poor quality audio and the difficulties resulting from transcription.

Three present or former subject coordinators, four present or former lecturers, and four current tutors of the subject were represented (some participants had had multiple roles in recent years). Of the seven participants, three were from a mechanical engineering background, three were from civil engineering, and one had a civil geotechnical engineering background. Of the academic staff normally charged with teaching engineering Mechanics, these backgrounds and responsibilities provided a balanced representation of engineering discipline focus.

Interviews ran from 30-55 minutes, depending on how much each participant had to say on each topic. As with the focus groups, the duration was determined by the participants and interviews were allowed to continue to their natural conclusion.

6.2.4 Analysis

A qualitative analysis of the research data was undertaken using two different approaches. Initially, a 'first-impressions' analysis was completed to identify themes within the interviews that are immediately apparent to the researcher. While efforts were made to limit the influence of the researchers' own opinions of Mechanics education, it was acknowledged that data could be skewed by the interviewers own priorities. Conducting this 'first-impressions' analysis meant that the outcomes as seen through the authors own interpretation are reported here for clarity and completeness. The results reported here were drawn and adapted from previously published work (Goldfinch, Carew, & Thomas, 2009, 2011).

The second layer of the analysis was a more detailed analysis of the data aided by the qualitative data analysis software package, NVivo 8 (QSR, 2008). For this research, data were imported into Nvivo in text format (interview transcripts) and audio format (focus group recordings). Sections of data, whether text, or segments of audio recordings, were highlighted and coded against 'nodes', which are user defined categories or themes. Once the data was coded, a visual representation was created to illustrate what proportion of a dataset had been highlighted against each node. This can be created for individual data sources (in this case interview transcriptions or focus

groups audio recordings) or collections of data sources. Nvivo allows the user to analyse qualitative data by identifying prevalent themes or categories, or minor ones, in a manner that is consistent across data sources. This process made it easier for the researcher to discriminate between common themes and other issues discussed in brief, or made as one off statements.

The Nvivo analysis was conducted using a semi-inductive approach by reviewing transcripts of text from the academic staff interviews and ‘free coding’ (Bazeley, 2007). This free coding was informed broadly by the intentions of the interview questions, which indicated some basic themes that should emerge through each interview and focus group (e.g. Positive/negative comments on teaching approaches, academic history etc.). Using the free coding approach, new nodes (or themes) were established as themes not considered in the question sets that emerged. Through this process a range of ‘free nodes’ were created during an analysis of the first three interview transcripts. These transcripts were then re-analysed using the full set of free nodes. The approach taken in coding instances was similar to what Bazeley and Richards (2000, p. 53) describe as ‘Descriptive coding’ where instances are tagged to be analysed at a later stage. Nodes do not provide the students’ or academics’ perspectives as such, but rather, describe the themes along which participants raised issues. Interpretation of participants’ perspectives’ is dealt with in this chapter through direct quotes, and comparisons of the focus on various themes between different participant groupings (students and staff). Due to the method in which nodes were established, these are presented in the results section rather than the method section of this chapter.

The third and final layer of the analysis was to observe any differences in emergent themes or points of interest between the first-impressions analysis and the results from Nvivo. This brief process was used to identify any biases that may have been imposed by the researcher and also provided an important quality checking measure for the research.

Codes have been used to identify participants and participant groups in the quotes reported below. These codes are described in table 6.3.

Table 6.3 Participant codes explained

Participant code	*Description*
SG1	Two students, one mature age, one school leaver, both domestic, both male
SG2	Three students, two female, one male, all domestic, all school leavers
SG3	Three students, two female, one male, all domestic, all school leavers
SG4	Three students, all male, all domestic, all school leavers
A1	Senior academic, has tutored, lectured and coordinated ENGG152
A2	Junior academic, has tutored, lectured and coordinated ENGG152
A3	Junior academic, only tutored ENGG152
A4	Senior academic, only tutored ENGG152
A5	Senior academic, has tutored, lectured and coordinated ENGG152
A6	Junior academic, only tutored ENGG152
A7	Senior academic, has tutored, lectured and coordinated first year Mechanics

6.3 Results – First impressions Analysis

6.3.1 Students' Responses

In all the focus groups conducted at the University of Wollongong, student participants were unexpectedly forthright and articulate in their responses. Very little encouragement was required for participants to elaborate on their statements and continuous group discussion was maintained for the duration of each focus group despite their small sizes. The groups were largely homogenous in makeup, with all participants except one being domestic full time enrolled and recent school leavers. The one exception was a domestic student in his late 20's, studying full time after a career in a trade level job. The makeup of the student participant group was unsurprising given the dominance of domestic full time students commencing study straight after high school in the first year engineering cohort at UOW. However, it may also have been influenced by the recruitment approach which targeted those who attended lectures and regularly accessed the SOLS mail system.

In terms of specific topics that students may struggle with in the subject, few common themes appeared to emerge. The topics students cited as being problematic varied from person to person and participants frequently disagreed on which topics were more challenging. This aligns with the research described in chapter five where some

mistakes and misunderstandings in their final exam transcripts appeared more common than others, but overall the mistakes made by individual students were quite diverse.

Irrespective of what students saw as difficult or straightforward, there was general agreement that the content in the two engineering Mechanics courses was relevant, useful, and interesting: "I'm enjoying the content, like, I know it's something I'm interested in" (SG4). In asking students about particular topics that were problematic for them there also appeared to be a limited awareness of the topics they had covered to date in ENGG152. Course outlines were often referred to by participants in order to establish which topics they had trouble with.

When commenting on their approaches to study, students indicated mostly assessment-led study patterns, an issue raised by Biggs (2003) and Ramsden (1992). It was apparent that many students preferred regular (weekly) assignments that enforced regular study. Frequent comments along the lines of "it's hard to keep yourself engaged in one thing when there's so many other things to do, and yeah you're pretty much just trying to keep your head above water, you don't really have time to absorb it" (SG4), supported the suggestion that students were predominantly concerned with meeting assessment demands. It seemed also to be the case that their quest for marks may have been hindering their ability to learn and engage with their education effectively. There were a number of comments made by students suggesting that assessment tasks in one subject distracted attention from other subjects and hindered regular study: "You're sort of just going from one thing to the next trying to get as many marks [as you can]" (SG2). For some students, weekly assessments in two other subjects run concurrently with ENGG152 often took precedence over study in ENGG152, which had less regular assessment in 2008.

Some accounts of study efforts by students indicated ineffective or inefficient approaches to independent study. Students reported spending hours trying to solve textbook problems unsuccessfully, with little to show for their effort. The effect of this appeared to be disheartening, particularly when they reported being unable to access assistance from staff when needed: "I even went to see one of the lecturers and he sort of made me feel like I shouldn't have gone to see him" (SG3).

When considering factors outside the university setting that impacted on learning in engineering Mechanics, there was little consensus among participants. Few considered socialising to have a great impact on their learning, with some participants noting that they did not go out regularly during session. Views on the impact of part time paid work were divided. Students who did not have work tended to believe full time study did not allow time for paid work: “when you’re doing something like this you don’t have time really for a job” (SG3). Students who did have part time work indicated that working was not a problem for them, often citing reasons that paid work was seen as beneficial: “I had too much time before… I was getting bored so this is filling in my time” (SG3). Indeed, from these focus groups it seemed the impact (or potential impact) of part time work may have been mitigated by the students themselves through their decision to work or not work. Closely related to this was the apparent stress caused by having limited funds: “sometimes it’s hard to come up with $1.70 each way every day to get to uni” (SG3). This issue may have also offset the challenges of balancing work and study for those who chose to take on paid work.

In all the focus groups there appeared to be a negative attitude to many aspects of the way the Mechanics subject was delivered and managed. The researcher noted that comments and discussion relating to negative aspects of the course seemed more deeply considered than the positive aspects. When asked to comment on the negative aspects most students readily responded with personal experiences and stories they had heard from their peers. These negative comments were recalled and recited more rapidly than positive comments. Regardless of the cause it was apparent that the negative experiences of learning in engineering Mechanics, and university generally, were at the forefront of their awareness. Any aspects of the course that may encourage student motivation and engagement (the positives) may have been overshadowed by the factors that may de-motivate them (the negatives).

When asking for their ideas on what would be helpful in engineering Mechanics, responses were quite narrow in scope but had a high degree of consensus. Peer assisted study sessions, or PASS (UOW, 2013), were raised in all focus groups without suggestion from the facilitator. The provision of many worked solutions to example problems was also suggested as very helpful. Laboratories and site visits were nominated as helpful for improving their understanding of Mechanics concepts.

However, the lack of range of ideas suggested by students was interesting. Participants tended to discuss their past experiences of what they had found most useful and made suggestions that were within the scope of the assistance and support they were familiar with. It seemed that participants were simply picking a 'best of' from the relatively limited range of learning experiences and support they already knew or had experienced.

6.3.2 Academics' Responses

The engineering academics interviewed at UOW offered some interesting perspectives, many of which contrasted with the student focus group findings. An area where academics' responses bore similarities to the students was the general focus on negative aspects of the teaching/learning process in engineering Mechanics. These negative aspects also appeared to be at the forefront of academics consciousness when it came to teaching. Other areas raised by academics that concurred with student comments recorded during the focus groups were:

- The volume of content in first year Mechanics being too large and the pace of its delivery too fast.
- Students' apparent assessment driven approaches to study
- The perceived usefulness of peer assisted study sessions (PASS) in helping students learn Mechanics.

The participating academics' views on what caused students to perform poorly in engineering Mechanics often referred to students' poor attitudes and approaches to study. These attitudes and approaches were expressed by academics who were interviewed as attributes brought into the course at the beginning: "to some extent they want to be spoon fed the information (A7) and First year they are babies" *(A1)*. Further questioning on the reasoning behind such assertions about students attitudes indicated that many anecdotes provided by academic participants focused on individual students or a very small group that may not be representative of the behaviour of the whole class. It is difficult to compare this situation with the data from the student focus groups as these participants appeared to be quite well engaged with their study. However, as probing by the interviewer revealed 'very poor attitudes' to be a minority problem, the overemphasis of this as a causative factor may have been one example of a focus on the most negative cases: in this case, the most disengaged students.

When asked about the positives in the Mechanics course, it was clear that the academics interviewed did not regularly receive the positive feedback presented by students during the focus groups. Responses to opening questions about the positives of the course and what students liked included: “Not something that has really been asked of students, hasn’t really cropped up” (A2); “Not really, I think they just attend the class” (A5); and, “Not a lot” (A7). While there are numerous positives to report from the students’ perspective, it appeared that there were limited opportunities for this feedback to be relayed back to staff.

In terms of the more specific issues surrounding engineering Mechanics education, students’ background in mathematics and physics was raised often, as was general high school performance as measured by entry rankings (UAI, now ATAR). At the topic level, similarly to the focus groups, there were a wide variety of topics reported to cause difficulty for students and no clear consensus on the most challenging areas.

Other outcomes of the academic interviews relating to course design were somewhat more difficult to report. Views on how the material should be delivered, how the subject should be structured, and how it should be assessed differed greatly between the academics interviewed. The diversity here may have been influenced by the diverse educational and cultural backgrounds of the group of academics interviewed. However, it was not possible to determine the reasoning behind these differing views.

6.3.3 Summary of first impressions analysis

This ‘first impressions’ analysis identified a number of key issues:

- Variation and inconsistency in the problem topics cited by students, and they often had difficulty identifying these.
- Students felt the subject content was useful and interesting, though both groups felt there was too much content in the course.
- Students are assessment driven, noted by both students and staff.
- Students struggled with independent study.
- Students’ perception of the impact of outside influences varied.
- Students and staff were both very focused on negative aspects of ENGG152.

- Students readily identified their preferred teaching modes, but only from those commonly used in engineering education. Peer Assisted Study Sessions were suggested by both sides.
- Academics were focused on students' low motivation and poor approach to study, arguments often supported by worst case anecdotes.
- Academics cited academic history as a problem.
- There were many different ideas presented in relation to course design and pedagogy.

While this analysis approach identified several key concerns in Mechanics education, a different approach to analysing the data was required to understand more about the nature and the extent of these issues. Following this analysis, the data were re-analysed with the aid of the qualitative research software package, Nvivo 8. The results of this more detailed analysis are presented in 6.4 below.

6.4 Results – Analysis using Nvivo

As discussed in 6.2.4, 'nodes' were identified in the process of analysing the data with Nvivo. The set of free nodes developed by the researcher based on interview and focus group data totalled 17 individual nodes. These are listed below, and described in detail in the following paragraphs:

- Academic History
- Concepts and specific content
- Content overload
- Course structure
- Outside influences
- Pedagogy
- Perception of concept difficulty
- Personal commentary – negative
- Personal commentary – positive
- Personal reflection on learning
- Student approaches to study
- Student motivation

- Timetabling
- Student responsibility
- Staff responsibility
- Institution or context responsibility
- Staff Motivation

Academic history included references made by participants to students learning and exposure to subject areas prior to commencing ENGG152. These references were made in either a positive or negative sense and related prior experience to subsequent performance in, or preparation for the study of engineering Mechanics.

Concepts and specific content includes references and statements made in regards to particular concepts or topics taught in ENGG152. For the most part, these references were negative commentary on the content students tend to struggle with, although many were also those which they were believed to have understood. This node provided insight into how focussed the participant was on subject content in the context of the entire interview. Specific quotes also show the commonly cited problem areas.

Content overload is related to *pedagogy* and *course structure*, but was such a common point of discussion that it was coded separately. References coded under this node related to the quantity of content that is included in ENGG152 and the effects this may have in various areas.

Course structure is also related to *pedagogy*, but refers specifically to comments on the manner in which the course was run and administered. This included references to the division of content, allocation of staff, assessment scheduling and so on.

Pedagogy in this application is restricted in its definition to face-to-face teaching practices, and the forms of assessment used. This node is supported by *Course structure* and *Content overload*.

Perception of concept difficulty maps where participants referred to the level of difficulty of a concept or topic. References coded under this node were important for understanding how participants view the learning process in terms of levels of difficulty or complexity.

Personal commentary – negative and ***Personal commentary – positive*** include comments made by participants which are of a personal nature, often relating to the learning process or outcomes of their efforts.

Personal reflection on learning charts instances when participants referred to their own experiences of learning, whether they are practices they used in the past, recollections of time as a student, or comments of a similar nature. Comments coded under this node often gave insight into preferred teaching practices in the case of academic participants, or active reflection by current students.

Student approaches to study referred to comments made by participants (students or academics) on the behaviour and practices of students in supervised or independent study.

Student motivation is similar to *Student approaches to study*, however, this node focused specifically on their motivation for study or the factors surrounding it. References made here were often the precursor or perceived causative factors in *student approaches to study*.

Timetabling was coded under a separate node as it was a frequently cited issue. Comments referenced under this node focused on class scheduling and its impact on a variety of other nodes, particularly *Student motivation*.

The three nodes ***Student responsibility***, ***Staff responsibility***, and ***Institution or context responsibility*** map instances where responsibility or blame is assigned to any of the three domains. This provided insight into the broader orientation of participants' beliefs of where the issue of high fail rates stems from.

Staff motivation was added during the analysis of student focus group recordings as many students raised the level of engagement of lecturers and tutors in the teaching process as an important issue. The node maps references to educators' enthusiasm and perceived motivation to teach, and participants thoughts on how this impacted on their learning. These references appeared in both a positive and negative sense.

Aside from nodes in which the orientation was specifically stated, references were coded under each node whether they were positive or negative statements. The purpose of this coding under free nodes was to capture the types of issues that participants saw

as important. Once these were identified, further exploration was conducted through analysis and interpretation of specific quotes. This process is covered in the results section.

In each of the interview transcripts, the number of references coded under all nodes was between 64 and 79, with two interviews lying outside this range at 45 and 93 individual references. This represents a somewhat varied rate of response on different issues among the academic participants. In the focus group audio recordings, the number of references coded for the three groups containing three participants each was 127, 135 and 153, with the group containing only two participants totalling 91 references. This represents a more consistent rate of response amongst the student participants.

The charts presented in Figures 6.1 to 6.21 below illustrate the results of the descriptive coding of participant responses during the academic interviews and student focus groups. The participant descriptions are along the x-axis. The percentage coverage on the y-axis is an indicator of the proportion of each participant or participant group's total response that was devoted to discussion in this area. These values are not an absolute indicator of the issues that were most or least important to participants because there were numerous other variables at play. Rather, they are a comparative indicator that can be used to compare the focus of discussion between participant groups. Discussion of these results was based upon this principle, and refers back to the purpose of each node outlined above.

6.4.1 Pedagogy

Figure 6.1 presents the most commonly raised and most talked about issue in both the interviews and focus groups, pedagogy. Under this node, instances where participants referred to teaching or assessment practices, either positively or negatively were coded. The chart shows no clear distinction between students and academics with regards to the level of focus on pedagogy during the sessions. Comparing academics, there was also no apparent difference between the prominence of pedagogical issues cited by academics with lecturing and subject coordination responsibilities, and those of academics with only tutoring responsibilities. This was also the case when the junior and senior academics were compared.

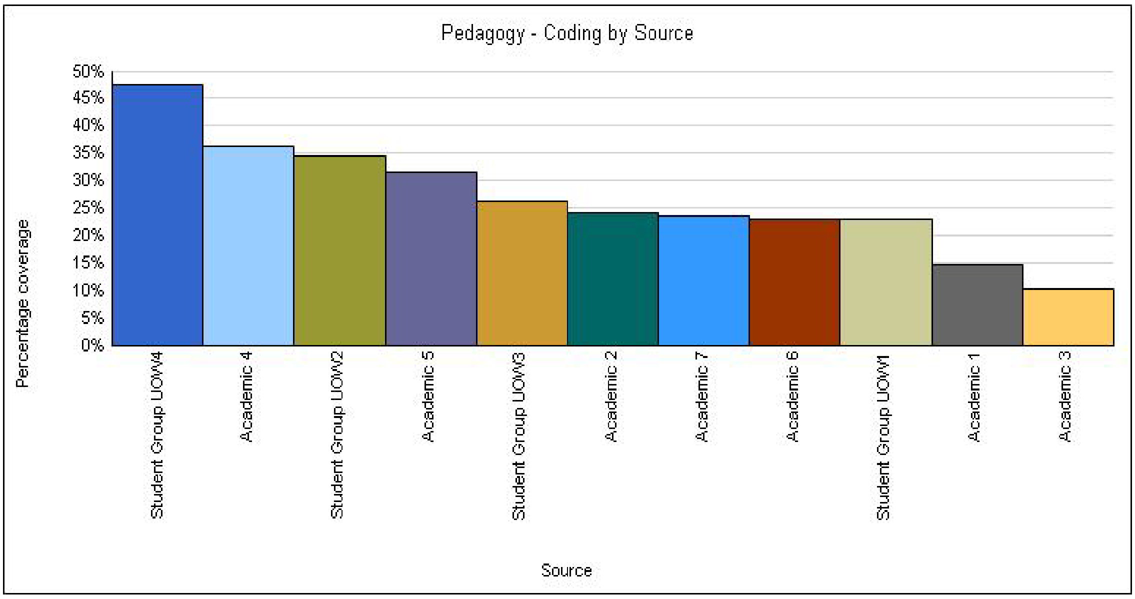


Figure 6.1 Pedagogy free node observed by percentage coverage

To explore issues around teaching practices further, *Pedagogy* was then broken down into components. The nodes *Pedagogy – Assessment*, *Pedagogy – Laboratory*, *Pedagogy – Lectures*, and *Pedagogy – Tutorials* were established initially as these were the primary teaching formats used in ENGG152. Following this, as coding progressed, the nodes *Pedagogy – PASS* and *Pedagogy – Other resources* were also established. To present the coded data in a comparative manner, Figures 6.2 – 6.5 show the percentage breakdown of selected Pedagogy nodes for student groups, academic participants who held lecturing/coordination roles in ENGG152, and academic participants who held only tutoring roles. Figures 6.2 – 6.5 highlight which aspects of pedagogy were more important to each of the participant groups. To understand just what these views are, it was necessary to refer to the actual comments made by participants.

The *Pedagogy – Assessment* node related to the current assessment methods used in the subject. Discussion included preferred modes of assessment that were not used in the subject, and particularly with the students, a comparison of current assessment modes with preferred ones from other subjects taken by the students. From Figure 6.2, students were clearly more focused on assessment as an issue than academic participants. Concerns of students focused on in-class quizzes, noting in particular that they were stressful and didn't give them an opportunity to correct their mistakes.

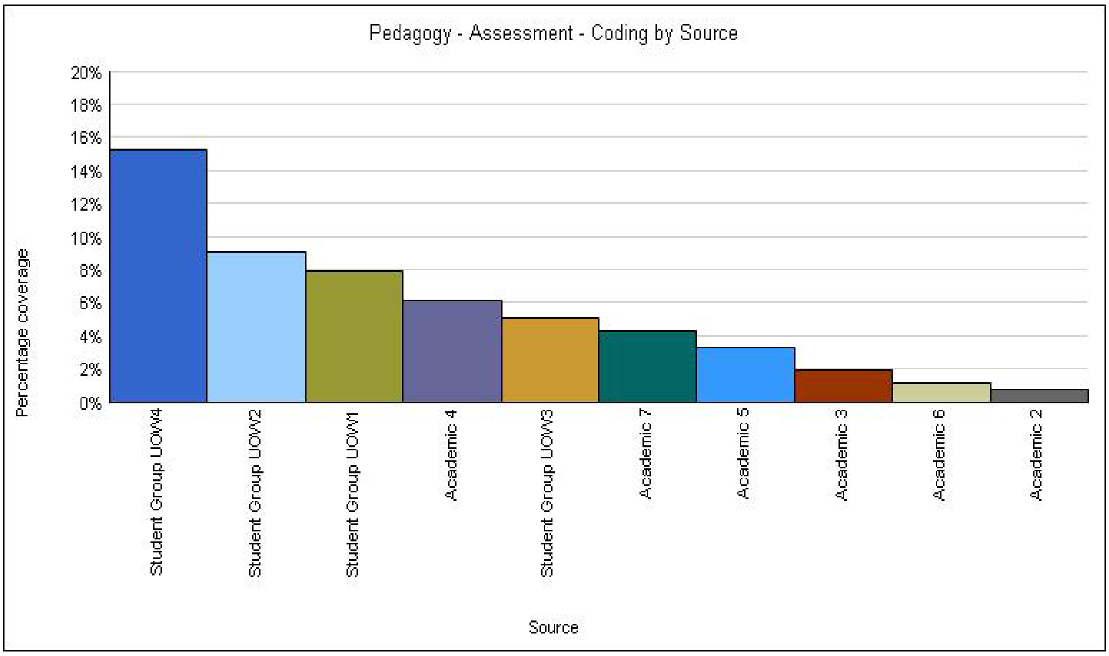


Figure 6.2 Pedagogy – assessment node

One academic highlighted an issue with student performance in class quizzes "when it gets to a quiz or final exam question that's slightly different, even if they've studied quite a lot, they might struggle with how to approach it."(A2). This view is in contrast to one typical student response that quiz questions "seem unrelated to anything we've done... if you look through later you'll find it in the book but we won't have done anything similar to it" (SG2). This suggests a possible over estimation by the academic about how much the students are likely to understand about the content. This is a similar finding to Streveler et al (2006, see 2.2.2) who identified frequent misjudgments by academics as to how well students understood topics.

An area where a level of agreement existed between staff and students was in relation to formative assessments: a staff member stated "I think ah, project type of assignment rather than just a weekly tutorial could help them understand" (A3), whereas a student observed "Maybe if... after the tutorial we get given an assignment or something on what we've been doing in the tutorials, and bring that back the next time we have a lesson" (SG4). Students also highlighted the desire to have continuous assessment, as there was concern that the quiz dependent arrangement might have promoted inconsistent study: "in statics and dynamics, we've only got these little quizzes and then a massive one at the end... everyone says it, they don't do anything, they're just going to cram for the one at the end"(SG1), "So I haven't really been doing much for 152 at all unless there's been like prep work for the lab or if I've been trying to study for the

quizzes” (SG4), and "You don't learn as much if you cram for the final exam as if you study for an assignment every week, because then the final exam is not a true indicator of how well you know the subjects."(SG3). In defence of the quizzes, students did pick up on the original intention of implementing them: “we replaced that by having a quiz based on the questions that had been set, that you had to prepare for that tutorial… That had the advantage of focusing people on what was going to be important, and highlighting to people when they didn’t know something early on” (A4). As one student noted, “I like the quizzes because you get [feedback]” (SG3), though this view was a minority one within the group and the student agreed with their peers that quizzes and exams were stressful. There were also a number of issues reported by students around inconsistent marking of the quizzes, though this was not mentioned by any of the academic participants, including two who were specifically referred to by students as inconsistent in their approach to marking.

Laboratories were also discussed by all student groups, and by one academic in particular, these references were code under *Pedagogy - Laboratories*. However, as the percentage coverage in figure 6.3 shows, this was a much prominent topic of discussion than assessment. Only Academic 5 talked about labs in terms of their potential benefits in helping students to see and touch Mechanics concepts. Other comments from academics related more to the administrative side of how the labs were run. Students’ commentary on laboratory based learning was much more detailed. Some cited learning benefits and were very positive towards laboratory exercises and practical work "it's sort of good to see where the stuff you do in the lectures and tutes, where it can be practically applied. I think that's really important to sort of apply what you're learning" (SG1). Other students expressed less satisfaction with the usefulness of the labs "I see the point but they don't help with work in lectures and that" (SG3), and "I look at them separately, the labs and the lectures, like I don't really relate them" (SG3). Student statements seemed to indicate a disconnect between laboratory classes, lectures, and tutorials. From one academics comment (a tutor who had also worked as a lab demonstrator), students’ appreciation of the purpose of labs may be more widespread “The biggest problem we’ve got with the labs, is nobody reads the manual beforehand, 2 out of 108 read it for me” (A7). In all, most students were generally positive toward labs as a teaching mode, with negative comments mostly limited to unhelpful lab demonstrators, and disconnection between labs and other teaching modes.

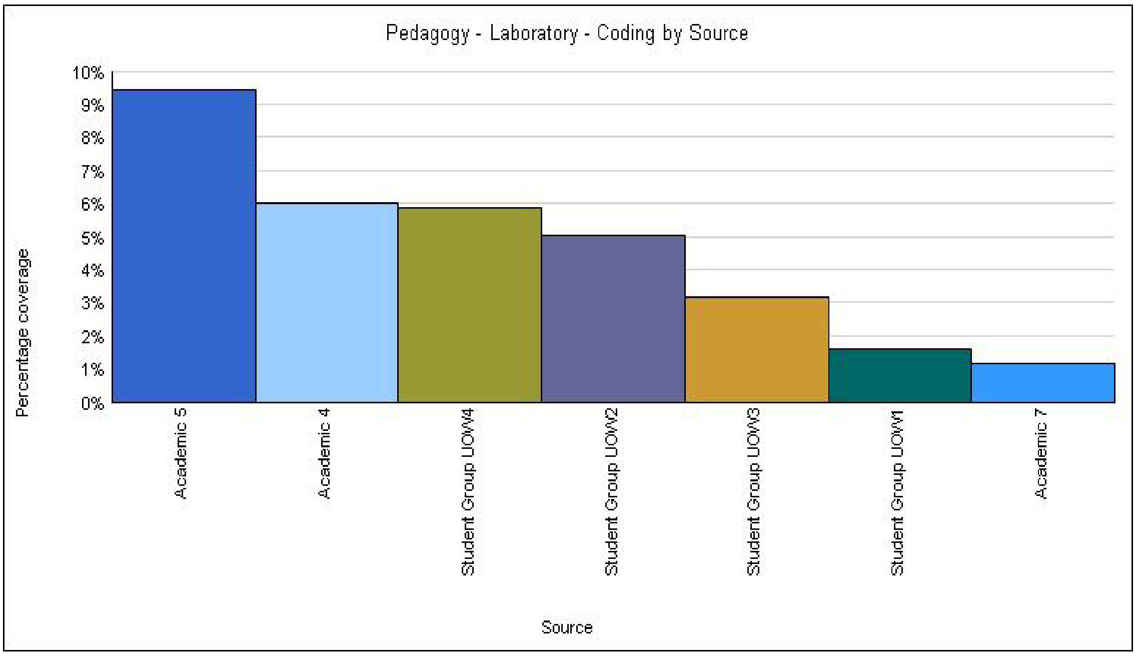


Figure 6.3 Pedagogy – Laboratory node

Figure 6.4 shows the coding at the *Pedagogy – Lecture* node. Here it can be seen that two academics who had lectured ENGG152 (Academics 1 and 2) spoke at length about lectures, followed by the student groups and another past lecturer (academic 4). Only three of the four tutors commented on lectures at all. Academics 1 and 2 expressed concern over how to engage students in the lecture setting. “I don’t think they like the lectures… Why? There is no eye contact, I cannot see them, they cannot see me, because it is so big.” (A1), and “I’m planning on mixing up the lecture this time so there’s a bit of theory as well as some examples, and working model as well just to break up the monotony of the theory” (A2). Students were also concerned with how engaging the lectures were. Some students commented directly on the approaches taken by each academic: “with [A2] that was a really good way he did that… started with the problem, got people involved with explaining it, and swapped between the problem and the theory”, a comment typical of many; and “[A1] just stands behind the podium the whole time and it’s not particularly engaging”. Students and academic participants both cited different approaches to lecturing that engage students, often referring to scenarios and lecturers outside ENGG152. However, it was apparent from responses that no student feedback was being relayed back to staff in real time. While students commented on specific instances of favoured practice with regard to lecturing, most comments indicated a generally negative perception of lectures as a learning mode.

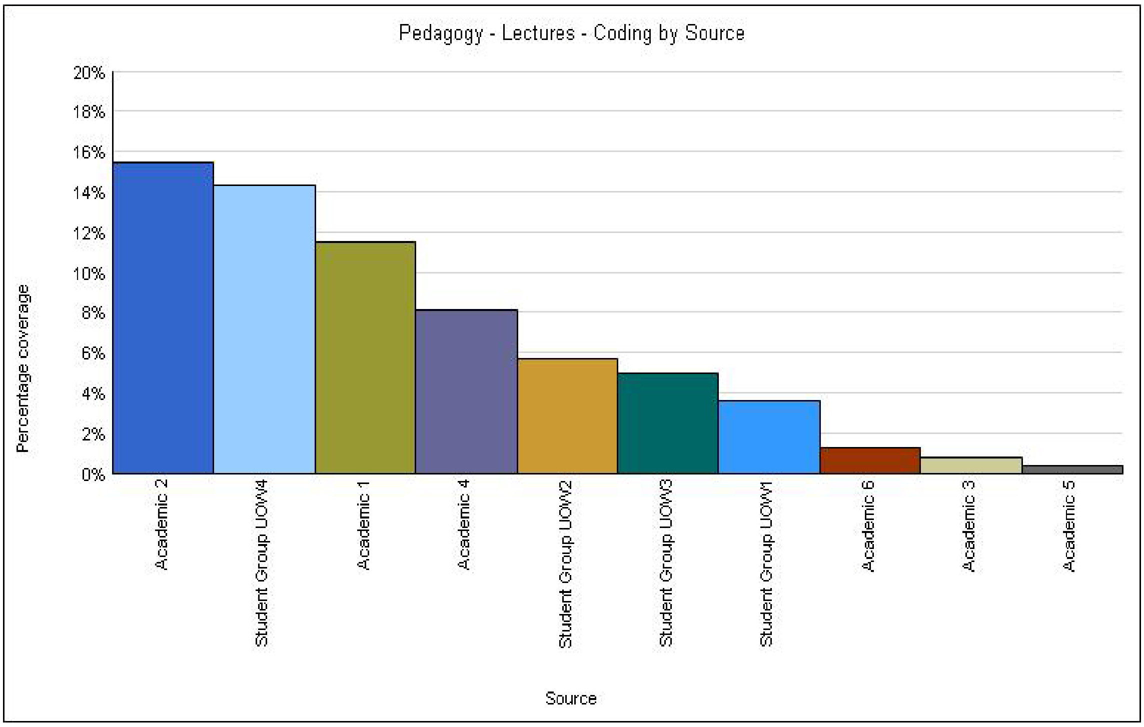


Figure 6.4 Pedagogy – Lectures node

A significant amount of time was spent discussing tutorial classes. These comments were coded under *Pedagogy – Tutorials*. In terms of participant groupings, the time spent discussing tutorials did not appear to be associated with any particular participant attributes. Comments from student participants indicated that students were quite positive toward tutorials as a teaching mode, with the majority of participants indicating tutorials as a preferred format: "I really like the format of the tutorials, how you go through a question and you can ask 'why is this like this?'… I get a lot more out of the tuts than out of the lecture" (SG1). Exploring deeper what students thought of the tutorials, it became clear that the approach taken by the tutor themselves was paramount. "She's a really good tutorial teacher, she'll go through anything that we ask her to, if she doesn't understand it… she'll actually make the effort to go through it with us and make sure that we understand it" (SG4), this quote typifies the kind of approach favoured by the student participants. However, it seemed that this approach to tutoring was not universal. Most of the student participants complained that one or both of their tutors (each class had a separate tutor for statics and dynamics components of ENGG152) were unhelpful or under prepared: "other tutors just go 'oh you should just know that it's high school" (SG1); "it's a real effort for them to do a full tutorial problem for us"(SG4); "you can tell if they don't really care and they're just trying to

kill two hours… like they've got bigger fish to fry" (SG2); "our tutor doesn't get given the tutorial problems early enough to look at it before hand… half the tute is spent with her trying to go through all the solutions and understand what they've done, and if she doesn't understand it then that's it, she can't explain it to us"(SG3). In fact, students' preference for statics or dynamics was in some cases directly related to their tutor: "I like dynamics, sometimes I find statics a little bit easier with some things, but we have a really good tutor for dynamics" (SG4).

Another issue noted by students was their perception that tutors expected too much in the way of independent learning: "it was just assumed that we'd seen all the equations before and we knew how to use them… they just assumed we knew how to do it all" (SG1); "They tell us to think for ourselves but if you have no idea where to go, you can't start" (SG2). These comments indicated a mismatch between what tutors were expecting of students and how students understood their role in the classroom.

The Academics' perspectives on independent learning offered further insight on expectations: "In the tutorial I give the students some time before I solve the tutorial questions on the board… usually I don't go into details of the solution I just write the equations and say "ok you solve it" (A1); and, "I'm sure the tutors will go through one or two on the board and then let the rest for students to do during the tutorial. So that should be enough to get them [through]" (A3). On tutor motivation and involvement: "So, you know, we've got these guys who are so busy with research that they're not going to get involved with first years, so you're relying on people that are in it for a bit of pocket money" (A7); and, "We also need active tutors to help the students as well, if the tutor doesn't have any motivation to push the students to the point that they should be then that really is an issue" (A6). It seems that while academics acknowledge some of the key issues raised by students, there are clearly different expectations of what tutors should be doing in class. The students want the tutors to lead, and the academics expect the students to take charge. One clear example of the effect of this issue is summed up by frustrations expressed by one academic tutor: "I always try to ask some questions, 'how would you do this, how would you do that'. I mean sometimes someone responds, but on most occasions it's pretty difficult to get any response" (A5).

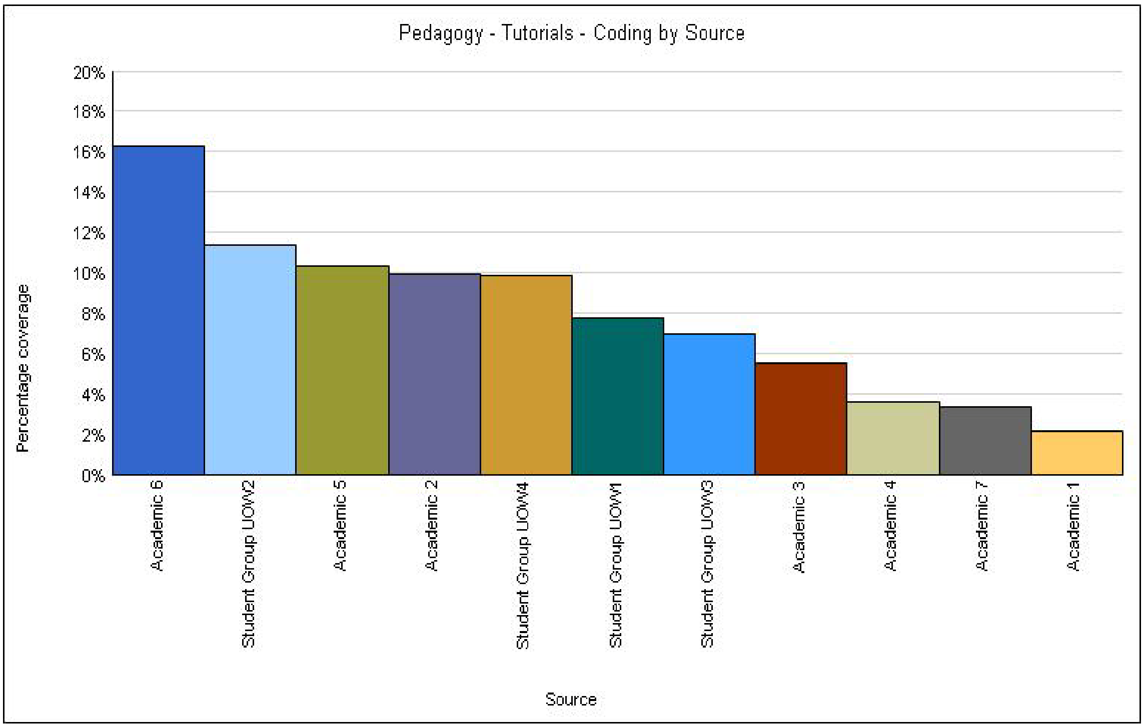


Figure 6.5 Pedagogy – Tutorials node

The node *Pedagogy – PASS*, covers references made to the need for the Peer Assisted Study Session program to be established in ENGG152. This question was not asked by the facilitator in any of the focus group sessions, but was raised by participants in all focus groups and met with universal agreement by other participants; "I find it hard that there's not a PASS subject or something like that… because it's one of the harder subjects I thought they would go to the effort to set up something like that" (SG2); "definitely PASS sessions… we've got PASS in chemistry, we've got PASS in maths, we've got PASS in Physics… I learn more in PASS than I do in anything else" (SG3). Students felt strongly that this would be a helpful addition to the subject, and several participants reported awareness of or participation in independent student study groups. However, despite this apparently unanimous agreement by students, only two academic participants (A4 and A6) mentioned that PASS was needed. It is worth noting that a PASS program was implemented in ENGG152 in 2010 and 2011 with no discernible impact on the pass rates in this subject.

The final node that formed a component of *Pedagogy* was *Pedagogy – Other resources*. This node captured participants' references to other resources available for ENGG152 or desirable additions to ENGG152. Most of the discussion here focused on the textbook and the availability of worked solutions as a learning resource. On both of

these counts the views of students and academics wore almost polarised. Students felt that the textbook was unhelpful and they wanted more worked solutions to aid their study: “the textbook we’ve got, as you go through the chapters, every so often it stops to introduce new material and you only get three or so… worked examples… it’s nice when you have a textbook that has a lot of fully worked solutions”(SG2); “In our books we don’t have many examples” (SG4); “I figure stuff out by getting it wrong, then looking at the worked solution and figuring out what I did wrong” (SG3); “I think it’s really, really helpful having worked solutions… I spoke to one of the tutors and he was saying that he doesn’t think we should have access to worked solutions to problems because it makes us lazy and not do it ourselves” (SG1).

Academics views on textbooks differed to those of students. Academic comments on the topic included: “In the textbook there are hundreds of these examples. These textbooks, you know, are written at such a detailed level with so many examples, I don’t think we need to repeat it again and again” (A5); “they have a lot of examples already from the textbook, we should not give them any more” (A3); “We have a textbook with lots of worked examples, so that’s important” (A4)”. Despite these differences, there appeared to be some common ground between the students and one academic. One academic remarked, “Some students said that's useful because they have a go at the problems first, and then check, but I've come across quite a few students who think that just because they've got the master solutions they don't do any work” (A7), while a student commented, “but I know people who just don’t turn up to tutes because they have the worked solutions” (SG3).

Academics and students commented on the benefits of extra, out of class consultation: “I think over 90% of the people who come to their lecturers during their consultation period end up passing the subject. And that’s probably a combination of the fact that the people are motivated to get on top of the problem that they’ve identified… and it gets explained to them better on a one to one basis than in a lecture or a tutorial” (A4); “[he] comes round to the college on Tuesdays just to help us out, which is really good” (SG4); “you get ten times as much just going and talking to someone for 10 minutes about the topic than studying an hour just by yourself” (SG2). These comments were related to the good practice approaches to tutoring suggested by students. It was evident that close contact between teacher and student was viewed favourably by students.

6.4.2 Student motivation and approaches to study

Often reported alongside pedagogical issues were students' approaches to study. Figure 6.6 shows that *Student approaches to study* was the second most common node referenced by participants. Again there is no clear indication on whether students' approach to study is a bigger issue for academics or students. Like Pedagogy, this result seems to suggest both parties in the educational experience considered the student's study habits to be an issue worth discussing at length. The key theme emerging from the academic side was the amount of effort students put into their studies: "I would say probably about 10% of the students do adequate preparation, and maybe 1% does adequate preparation for a lecture which is looking at the reading beforehand" (A4); "Some will do zero, absolutely zero. Some will do 6 hours [independent study]" (A1); "You try to emphasize… that we are there to assist in the tutorials so they should have at least attempted a question… so that they've got some specific questions they can ask, rather than just staring blankly and waiting for something to be written on the board" (A2); "we expect students to work through the lectures and the textbook, and come to the class or the tutorial prepared. They come unprepared, so simply they don't spend time, they don't work through examples, work through the problem" (A5). Academics were focused on the level of preparation students had coming into class, and statements indicated a belief that this issue was widespread. It was evident that students took a very different view on preparation for class: "they also expect that you go out and look for [information] yourself… everyone says, you know, 'this isn't school, we're here to not teach but to let you learn'… I don't like that" (SG4). In other comments, not referring directly to tutorial preparation, students expressed an interest in reviewing tutorial materials after the tutorial, rather than before, as though seeing lectures and tutorials as preparatory activities. This again relates to comments coded under *Pedagogy*. There is an apparent expectation from students that the lecturer or tutor leads the class, and they follow along.

The students readily suggested that they are not doing enough study, "I think if I spent eight hours a week I'd be doing well" (SG2). However, most cited a range of reasons why they can't or don't do the requisite preparation: "with all the subjects you're sort of going from one thing to the next… you're always trying to get marks because there's so many assessable items" (SG1); "I tried studying at the start, but it's a bit hard with the textbook, like you just have the answers, and if you don't understand it, you're not

going to understand any of the other questions related to that topic, so I pretty much just gave up studying the parts I don't know about" (SG3). This indicated that the reasons for students not doing sufficient work outside class were more complex than simply their motivation to study. There is also the possibility that academics are making an assumption that students' should be working to achieving the best possible grades, whereas one student remarked: "P's get the degrees" (SG2).

While several academics expressed frustration about the difficulty in getting students to actively participate in class and to ask questions, some students often explained their reluctance to ask or answer questions: "one time I was concentrating on something said previously and got asked a question about what was happening now, and I was just 'ah, this isn't good, I wasn't listening'" (CG4); "I hate putting my hand up in lectures… if I don't understand it I won't put up my hand, ever… even if I have a question in the tuts I won't put up my hand" (CG3). These two students seemed to indicate that their reluctance to participate in class was caused by not following the pace or simply a lack of confidence.

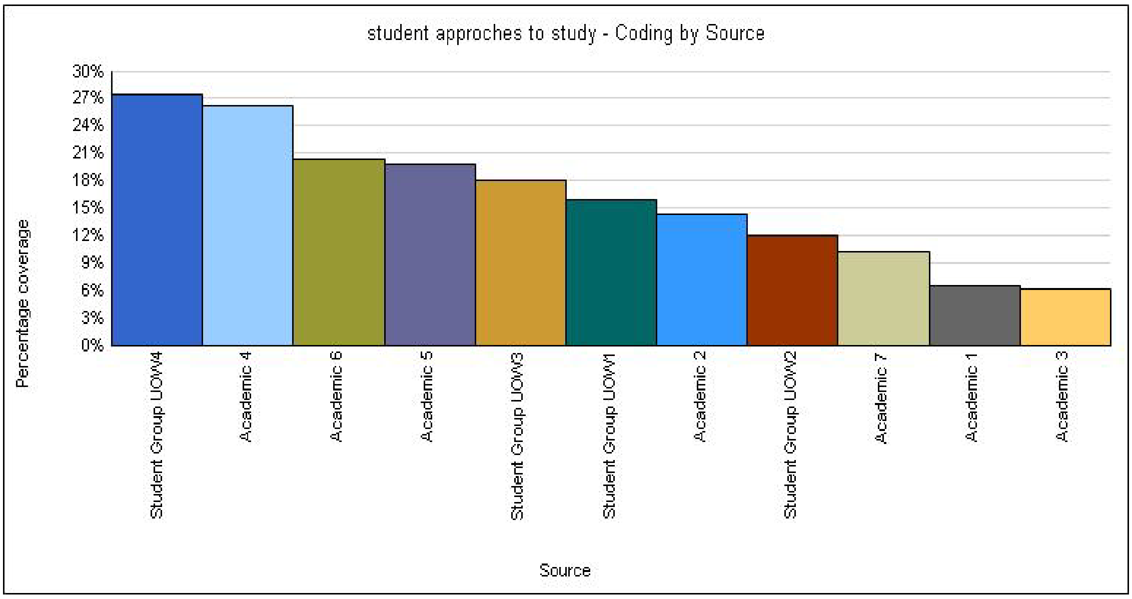


Figure 6.6 Student approaches to study free node observed by percentage coverage

Figure 6.7 indicates a more apparent divide amongst participants when considering student motivation in the educational process. This is perhaps unsurprising given the broad focus on this area apparent in the literature (see 2.2.2). In this graph, student participants appear to have lower levels of reference to their motivation towards study than many academics. Academics 1, 2, and 4 held lecturing and subject coordination

responsibilities for ENGG152, and devoted the largest coverage to issues of student motivation. There were many aspects of student motivation suggested by the academic participants, but a major consideration was why students didn't attend lectures: "you're not forced now to come to lectures and tutorials they don't necessarily feel inclined to turn up. They just want to access the information in elearning rather than come to the lecture" (A2); "this is maybe an issue in terms of the young adult learner, that they would, at that stage you probably don't have enough motivation to want to learn at 8.30 in the morning or whatever time the lecture has been set... they come and expect to be entertained and instructed" (A4); "there must be a sizeable number dislike the lectures because they stop coming, after about half way through the attendance drops off to about 50%. So seeing value in the lecture is obviously something that they don't" (A4); "they are not too enthusiastic. I mean most of them ask me 'why did I get one and not two', or the marking approach" (A5). These quotes show a sample of the variety of reasons proposed that can be summarised as disinterest, immaturity, perceptions of value, and assessment focus. These were all issues considered by other authors as reported in chapter 2 (section 2.2.2 and 2.3.2), and so it could be inferred that these perceptions of engineering students' response to learning in the lecture format are widely held by engineering academics, not just in Mechanics.

The students, though, offered some different perspectives on their own motivation, some of which were reported above in relation to the node *Student approaches to study*. In terms of enthusiasm for lectures, students reported "people only show up to what they have to" (SG1); "I don't think you should put in, unless you want to just ace everything, as much time as they ask" (SG2); "because there's no weekly assignments you don't feel pressured to study" (SG2). From these comments it seemed that the students were driven to participate and engage with the subject by the external motivating factors described by Kyndt et al (2011). This was in stark contrast to the academics interviewed here who appeared to expect autonomous motivation. One student did report the effects of a more autonomous approach to preparing for lectures: "I got so sick of lectures I stopped going after about week 3... except for this one today because I went through the lecture notes beforehand and it was helpful, but most week I wouldn't do that, I just don't have the time" (SG3). From this comment, it appears there are external factors that impact on autonomous motivation like time pressures from other subjects and commitments.

Like the student in SG3 quoted above, other students reported an initial commitment to study, but that various factors ended this: “this week was a good week for me getting 4 hours [study] through, though it still wasn’t in my test... the past few weeks I’ve just been like ‘nah stuff it, if I study I’m going to do the same as if I didn’t study” (SG3); “I tried studying like at the start, but it’s a bit hard with the text you just have the answers, so if you don’t understand it you’re not going to understand any of the other questions related to that topic, so I pretty much gave up studying” (SG3). Both these responses suggested that students in group three in particular were becoming overwhelmed by the difficulty of the content and gave up rather than explore alternative approaches.

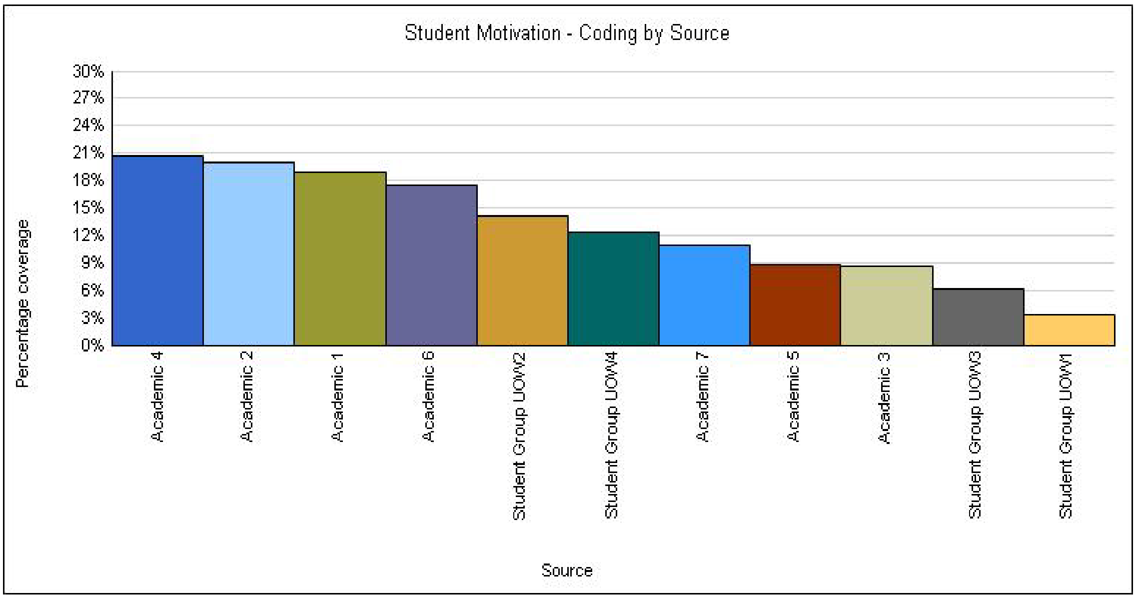


Figure 6.7 Student motivation free node observed by percentage coverage

6.4.3 Course structure

Compared to other nodes, the amount of discussion on course structure, shown in Figure 6.8, was more consistent across participants. Many different views were expressed in regards to assessment weightings, allocation of tutorial, laboratory, and lecture time, and the alternating weeks of statics and dynamics, which was the structure of delivery for ENGG152 at the time of this study (see 3.1 for full details on course structure). With regards to the alternating weeks of statics and dynamics, opinions were divided between all participants. There was agreement, however, that ENGG152 was seen as two separate subjects - statics and dynamics - with students struggling to see the links between them: “one of my biggest problems is that… [ENGG152] is split into two subjects, both two massive subjects” (SG1); “I’d like it if they had a mid-session exam where you do statics, then you do dynamics in the final” (SG2). This divide between

statics and dynamics was not unique to ENGG152. This separation is and reinforced in the major texts in Mechanics (Bedford & Fowler, 2008a, 2008b; Gray, et al., 2010; Hibbeler, 2009; McMahon, 2007; J. L. Meriam & Kraige, 2008a, 2008b; Plesha, Gray, & Costanzo, 2010; Pytel & Kiusalaas, 2010a, 2010b) and in the case of ENGG152, the responsibilities for teaching each component that were split between the schools of Civil, Mining and Environmental engineering (CME) and Mechanical, Mechatronics and Materials Engineering (MMM).

Many participants expressed a desire for more time to be allocated to the entire course, with one academic reminiscing about their time as a student when similar subjects were taught over a much longer period: "the academic year was 30 weeks, and I can say about 25 weeks was for statics, and probably 5 weeks was for dynamics… Whereas we are now having 6 weeks, can you imagine the difference between 6 and 25?" (A1); "we don't have enough hours spent on our part, the statics part… it's five or six weeks or such a complex topic" (A5). Students wanted more tutorial time, largely through a PASS program discussed earlier. It was clear to see that student participants also considered the current time allocation for the content of ENGG152 to be insufficient: "they throw a huge amount at us" (SG2); "I don't think there is enough class time every week" (SG2); "more spread out so we can get more engaged" (SG1).

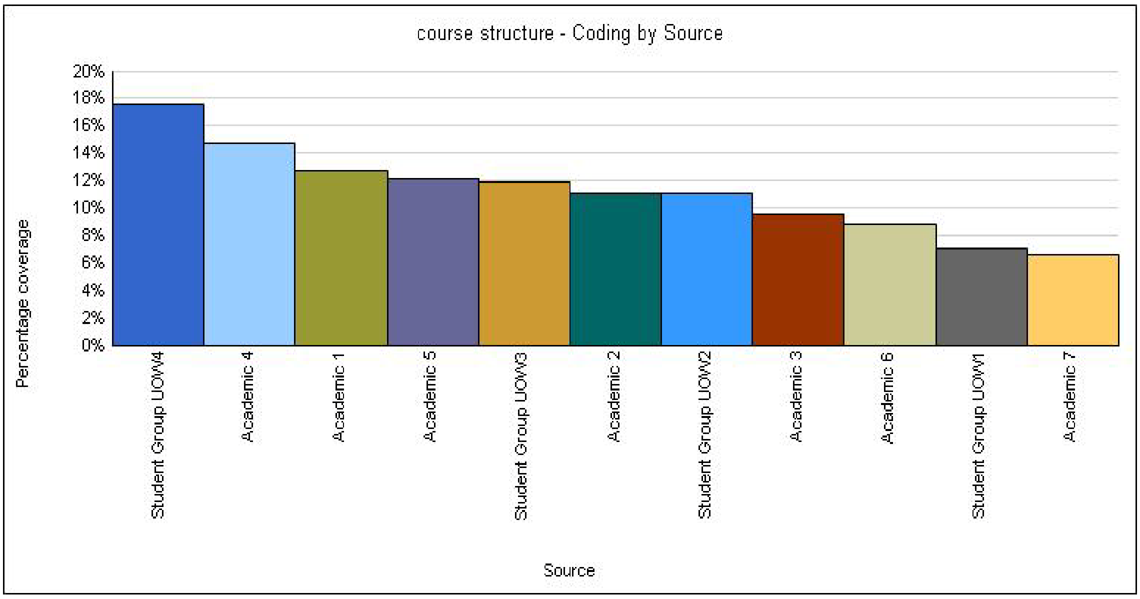


Figure 6.8 Course structure free node observed by percentage coverage

6.4.4 Academic Background and Content

The issue of academic history and its impact on learning in Mechanics was discussed during all interview and focus group sessions. However, despite this being a question posed by the researcher in each session, Figure 6.9 illustrates that most participant groups made only brief comments. In most cases the comments discussing the impact of academic history were short, but expressed with a high degree of confidence and certainty. In particular, students ability in mathematics was of key concern: “I think a lot of them have trouble grasping the mathematical side of it as well which isn’t specifically dynamics related, but it depends, I guess, on what sort of maths they’ve done in high school” (A2); ‘for those students who really dislike engineering Mechanics, it can be said that it’s because of their poor math background” (A3); “The mathematics background, obviously the more mathematics people have done the easier they find first year” (A4); definitely prior mathematical background. It’s not heavily mathematics, but it requires math background skills” (A5). The student participants were equally confident in their views: “I think if you’ve got maths then you’re pretty much covered in most subjects” (SG2); “I don’t think I could ever possibly do this if I didn’t do maths” (SG3). Similar views were expressed in regards to other Higher School Certificate subjects, Mathematics, Engineering Studies and Physics. A few academics also commented on the importance of entry rankings.

Student participants who had not done a particular subject in high school such as high level mathematics, physics, and engineering studies saw themselves at a disadvantage: “I’ve had no exposure to this sort of stuff before… so I would have preferred a bit more instruction to begin with” (SG1); “I didn’t do physics and engineering studies in high school, so I’m finding ENGG152 the hardest subject this session” (SG2).

The views expressed by participants in this study supported the findings of Chapter 5, that there is some relationship between academic history and success in engineering Mechanics. These views also provided insight into just what this relationship is. As one academic noted, “It’s not impossible for someone who’s done a fairly basic set of maths to get through, provided they do all the PASS program and the mentoring, take advantage of all the things that they’ve got going” (A4). As this indicates, a strong academic history may be an advantage but there are still opportunities for other students to catch up. This participant’s comment was also supported by other studies that have

shown that the advantage for students who had a stronger academic background fades coming into the second year of the degree (Dwight & Carew, 2006).

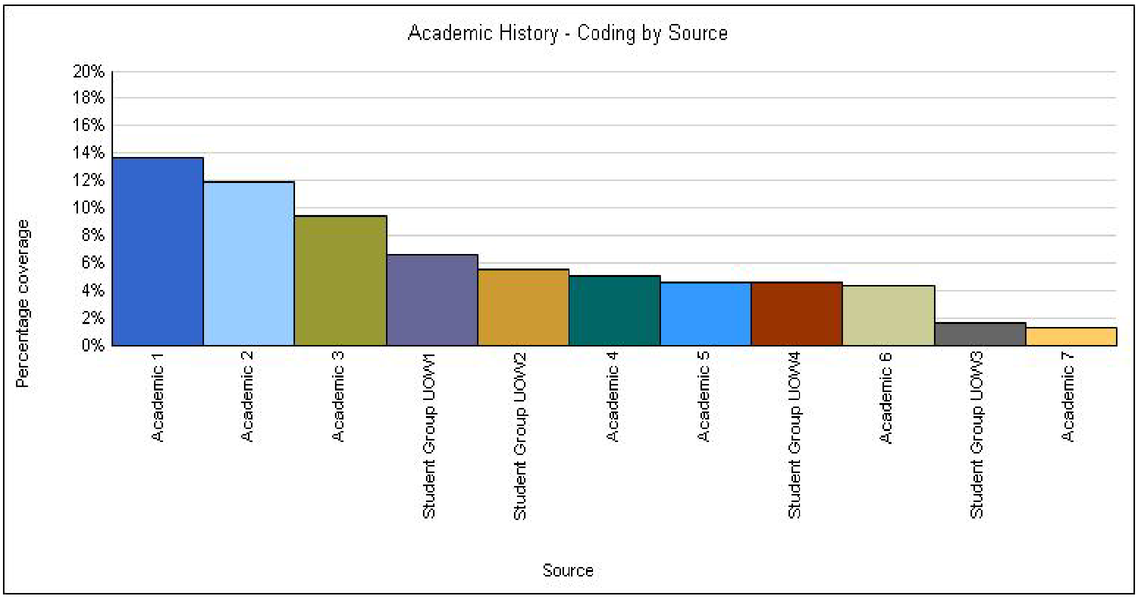


Figure 6.9 Academic History free node observed by percentage coverage

Reference to specific concepts or subject content was more common among academic participants than student participants, with the exception of UOW group one (see Figure 6.10). As well as only having completed two thirds of the subject at the time the focus groups were run, students often struggled to articulate the difficulties they were having or even naming topics. Students in groups 2, 3, and 4 all referred to their subject outline documents to identify topics they were comfortable with or had experienced difficulty with. As identified in the analysis of examination transcripts in Chapter 4, there were a wide variety of challenging areas cited. There was often direct disagreement about these areas in the student focus groups: “I like statics better” and “I like dynamics better” (both SG2). These two students also had opposing views on linear impulse and momentum that were at odds with their stated preference for statics or dynamics. Generally, Statics was viewed as easier than dynamics. However, the preference for either could also be swayed by the learning experience: “I prefer dynamics, but I think that’s more to do with the tutor” (SG4).

Challenging topics that were noted by several students and academics were curvilinear motion and rotational motion, relative motion, and vector analysis in three dimensions. Both student and academic participants’ views on which topics were easier to understand were diverse and no common themes could be reported. Aside from the

afore mentioned problem topics, most comments on specific topics where quite general. As can be seen in Figure 6.11, commentary on the level of difficulty was in fact relatively uncommon. Most academic participants refrained from making judgments on the level of difficulty of concepts, while students were more likely to. By comparing Figure 6.11 with Figure 6.12, it can be observed that despite all participants referring to specific concepts or content, commentary on the difficulty of these was quite limited. This seems to suggest that participants are reluctant to label any concepts as ‘hard’ or ‘easy’. The disparities in ratings of question difficulty that were identified in the analysis of exam papers (see 3.2.3) provided further evidence to suggest that the level of difficulty experienced by individuals in Mechanics was highly variable.

There were also a number of salient comments regarding the progression of topics from week to week. Two students in SG4 commented: “Engg152 is essentially a whole subject on the same stuff… for apparently the vast majority of us who find it difficult, it’s a whole subject that’s just a real struggle”, and “if you don’t understand what’s going on to begin with then you’re kinda stuffed”. One academic agreed with this statement: “It’s this idea that you must, it’s very sequential, that you’ve got to cope with week one before week two. And if you’ve taken a week off at any stage, you’re then grappling trying to catch up” (A4). These comments also related to issues around student motivation and approaches to study discussed above, where students tended to become overwhelmed when they fell behind. Some of the academic participants also commented on this issue, but from a different perspective: “So far, they still struggle with simple resolution of forces, which is very basic” (A1); “I would have thought that by now having done [ENGG101] they’d be reasonably good at it, but they either failed to draw a free body diagram… or they either don’t finish it correctly or leave forces out” (A2); “two things that I think get them struggling is understanding the concept of action/reaction.” (A3). From these comments it appeared that these academics had acknowledged that there are some students who struggled to grasp the most basic concepts in Mechanics. As the two students in SG4 suggested, understanding these underpinning ideas are preventing students from progressing.

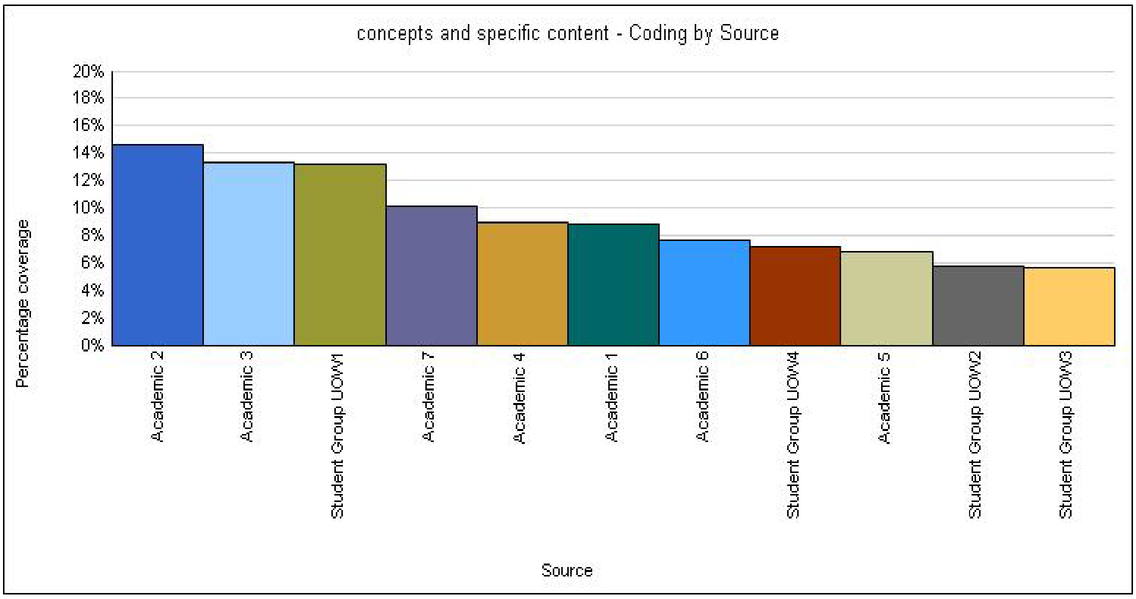


Figure 6.10 Concepts and specific content free node observed by percentage coverage

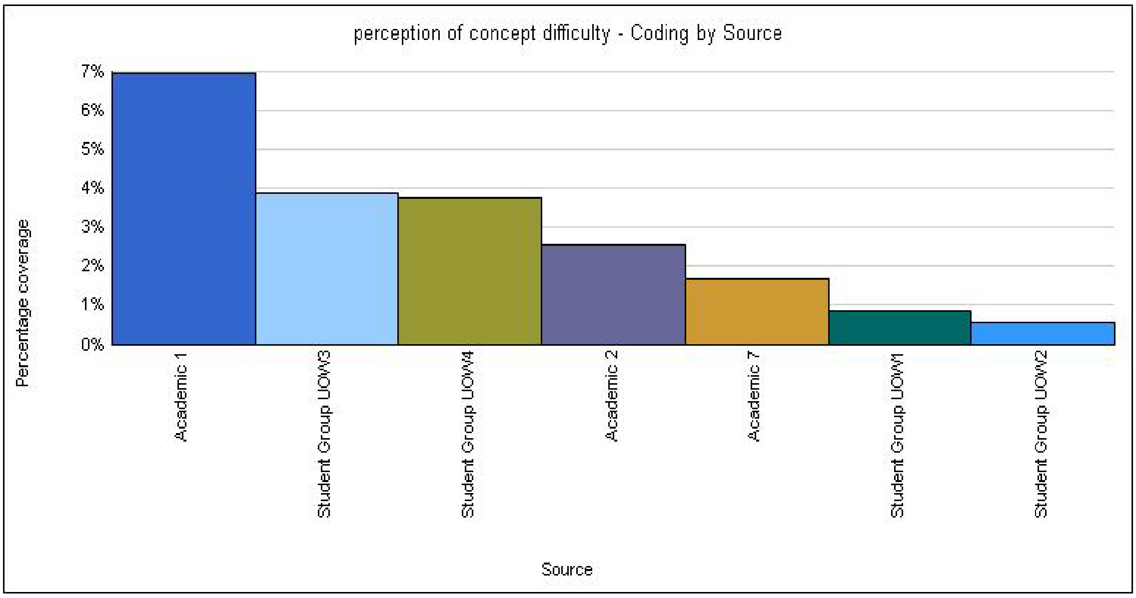


Figure 6.11 Perception of concept difficulty free node observed by percentage coverage

The issue of content overload was raised by all participants, with general agreement that there was too much to cover in the subject for the time available. However, only academics 1 and 5 discussed this at length (see Figure 6.12). Both of these participants noted that when they studied Mechanics the same amount of content was spread over a full year of teaching. One student summed up the effect of this overload: “I’m not really learning anything, I’m just getting everything that you have to do done, really” (SG1). This is very clear evidence of a surface approach to learning, a potential issue raised in 4.6 and highlighted by Ramsden (1992, p.182).

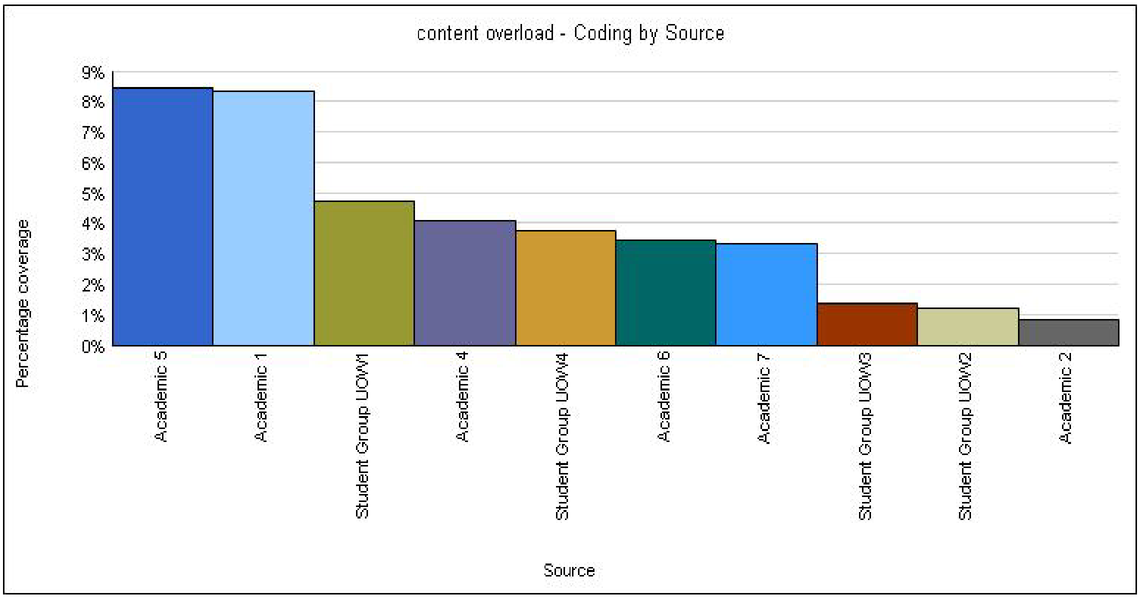


Figure 6.12 Content overload free node observed by percentage coverage

6.4.5 The Learning Experience

Immediately apparent in Figure 6.13 is the dominance of the student focus groups in commenting on their learning experience. This dominance is magnified by the fact that three of the seven academic participants did not make any reference to their experience of learning Mechanics. This was not a surprising outcome from the students' point of view because they were current learners of Mechanics and would inevitably consider their current experience. Academic participants that did refer to their own learning tended to frame their statements in relation to the way the Mechanics course they did was run, or the way Mechanics was taught in years gone by. Only academics 1 and 2 commented on their own learning experience directly: "I know that I always sit in the front so that I don't sleep. When I was a student I was always in the front" (A1); "Because they've already got the worked solution there, they may not even rework they question, they may just read over what they've got. I've found from my personal experience that reworking a question is a lot more useful than just reading what you've got written down" (A2).

None of the academics who raised these issues used their own experience of learning Mechanics to explain their observations of current or recent students. It appeared that these four academics had quite different experiences of Mechanics education than the current students. This may explain one student's comment regarding tutors and lecturers that "they just don't speak the [youth] language" (SG2). Students' preference

for PASS classes led by senior undergraduate students may also indicate that common experiences between student and teacher are helpful.

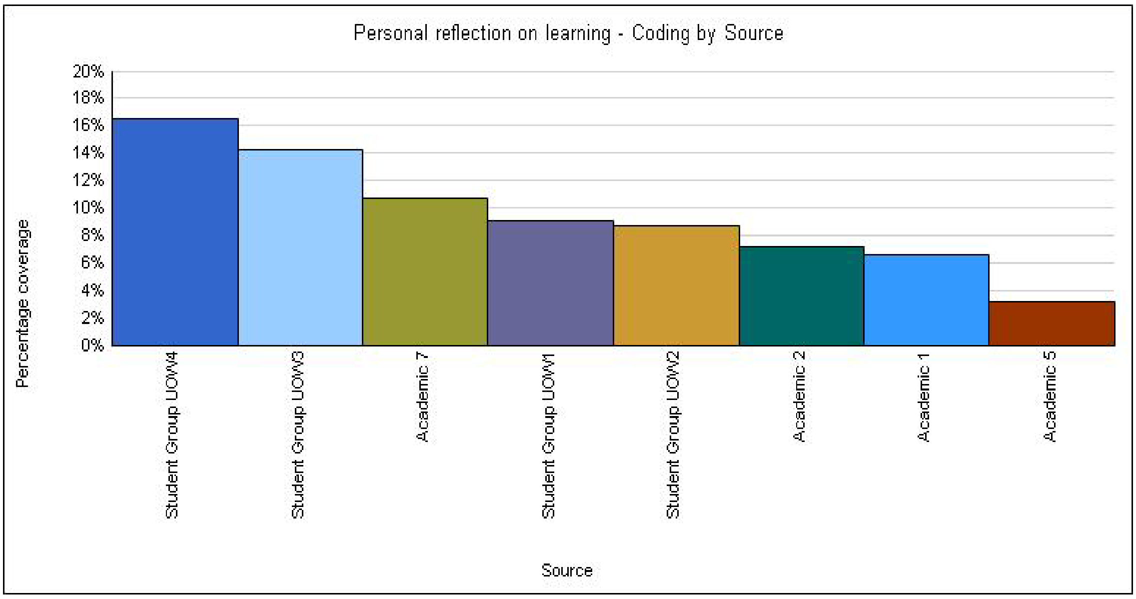


Figure 6.13 Personal reflection on learning free node observed by percentage coverage

The three nodes *Staff responsibility* (Fig. 6.14), *Student responsibility* (Fig. 6.15), and *Institution or context responsibility* (fig. 6.16) refer to any comments made by participants that assigned responsibility for an issue to one of these three areas. The purpose of these nodes was to explore if and how participant groups assigned responsibility to other groups or their own group. By comparing staff responsibility to student responsibility we can see quite clearly that student participants tended to assign responsibility to staff, while staff tended to assign responsibility to students. As far as the context of the subject and the institution, with a few exceptions, there was minimal responsibility assigned by participants to these.

This is one area which aligns quite strongly to the first impressions analysis discussed in 6.4.1. It was apparent that among most participants there is a tendency to focus reflection on learning outwards rather than self reflection. A situation appeared to exist where there were two sides to the learning experience with each assigning responsibility for issues to the other.

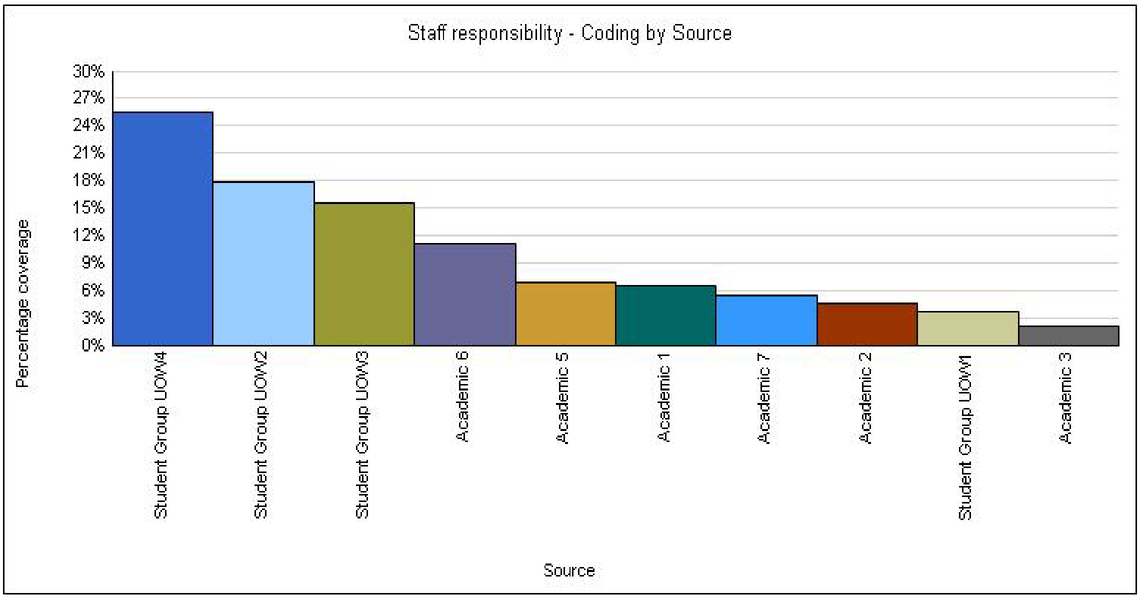


Figure 6.14 Staff responsibility free node observed by percentage coverage

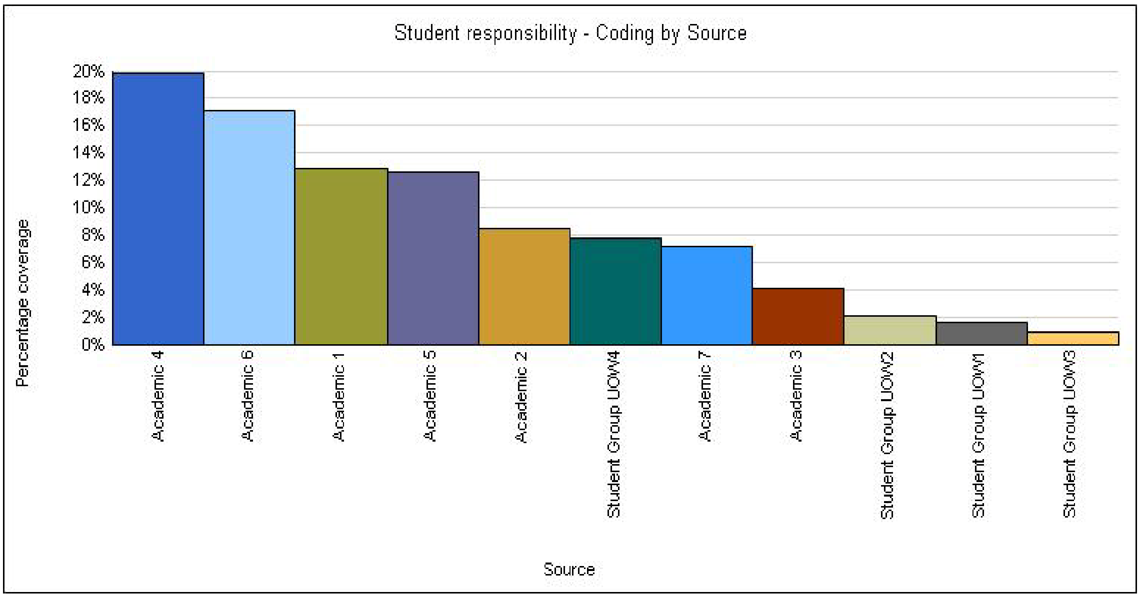


Figure 6.15 Student responsibility free node observed by percentage coverage

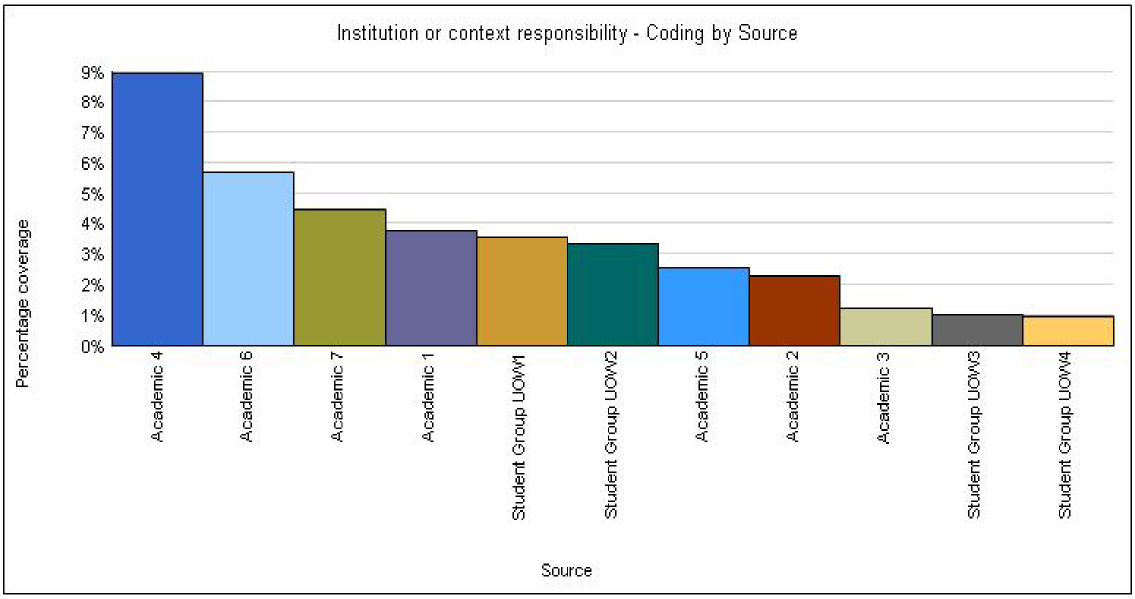


Figure 6.16 Institution or context responsibility free node observed by percentage coverage

Other nodes used in the analysis, *outside influences*, *content overload*, *staff motivation*, and *timetabling* received less universal attention from participants. Outside influences, including work, personal issues, other subjects, and so on received relatively little attention from most participants. Three of the academic participants did not refer to outside influences at all (see Figure 6.17). The issues cited were varied, as was the impact that participants claimed these had on learning. The two main areas cited by academics were distractions associated with part-time employment and ‘partying’: “I ask students who have failed why they think they have failed, they say partying, there is lots of partying” (A1); “occasionally a few will wander in a bit late because apparently it’s cheap beer night on [the previous night]” (A2); “A lot of students are working, part time or full time, and they will very often necessarily juggle their life around their work and so their studies come second” (A4). One academic offered an interesting insight into why students may not focus on their studies: “The other thing is youth, the kids are just too young to be treated the way they’re being treated at uni, and the model of learning which we aspire to, which is adult learning isn’t appropriate for 18 year olds who are expressing freedom for the first time” (A4). This particular comment seemed to suggest that many of the issues cited by academics in regards to distracted students, student motivation, and approaches to study made earlier in this section could be a result of unrealistic expectations placed on first year students.

The student participants' perspectives were quite different. The students tended to dismiss the issue of part time work, with some students stating that they didn't work as a result of their study load, while others had found jobs that provided a welcome relief from study. In the case of group two, the three participants all had very different views. The participants in this study did not see partying as an issue at all. One student offered a perspective related to academic 4's comment in the previous paragraph: "fair enough they expect us to be mature about it, but… you've gotta live, you can't just be cooped up with a pen and paper your whole life" (SG2). Other students stated that they socialised less during semester to account for time spent studying. The major concern the student participants had in regards to outside issues that impact on study were workloads and assessment deadlines for other subjects: "The workload of other subjects, it's huge" (SG1); "I got 45 for maths last session, so I've been concentrating heaps hard on that, and so I haven't really been doing that much for 152" (SG4). It became clear that the perceived impact of outside influences was a very personal issue, but with students tending to blame the university workload and academics concerned with activities outside university.

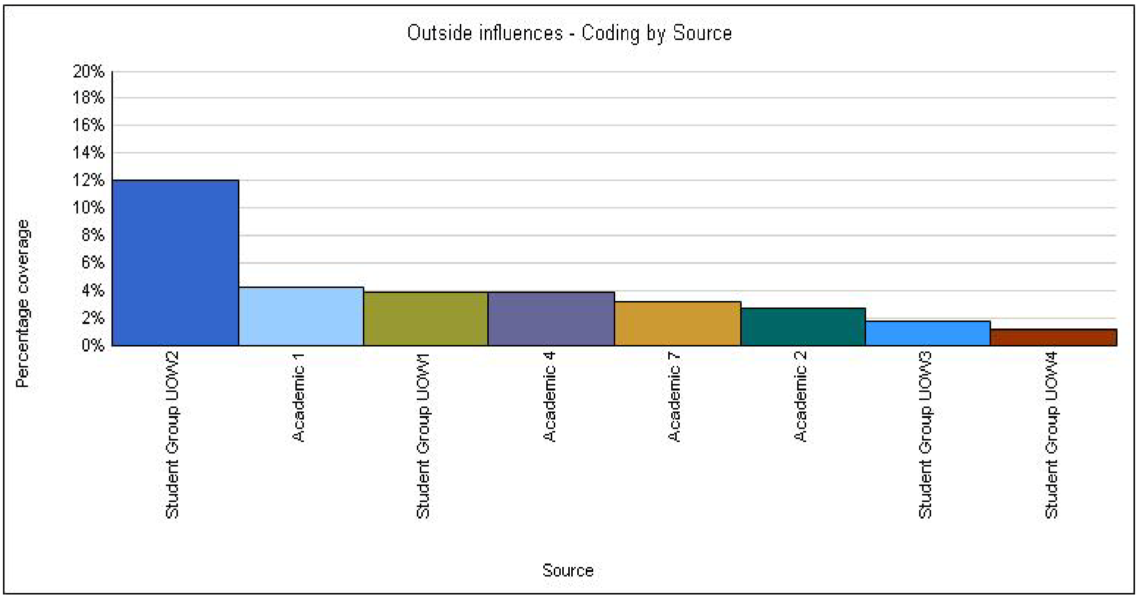


Figure 6.17 Outside influences free node observed by percentage coverage

Figure 6.18 suggests that the issue of staff's interest in teaching and engagement with the learning environment was discussed at length by academic 6 (a tutor) and student groups 2 and 4, and to some extent by group 3, but was not mentioned by other participants. Comments coded under *Staff motivation* indicated that these particular

participants had negative experiences with members of staff who appeared to have little motivation to teach. The comments from academic 6 only related to the need for motivated staff, and factors that were motivating for this participant as a tutor. Since this issue was not raised by several participants, this issue was not necessarily widespread. However, as most comments came from students and not the academics interviewed, it appeared that this problem was not widely recognised among staff.

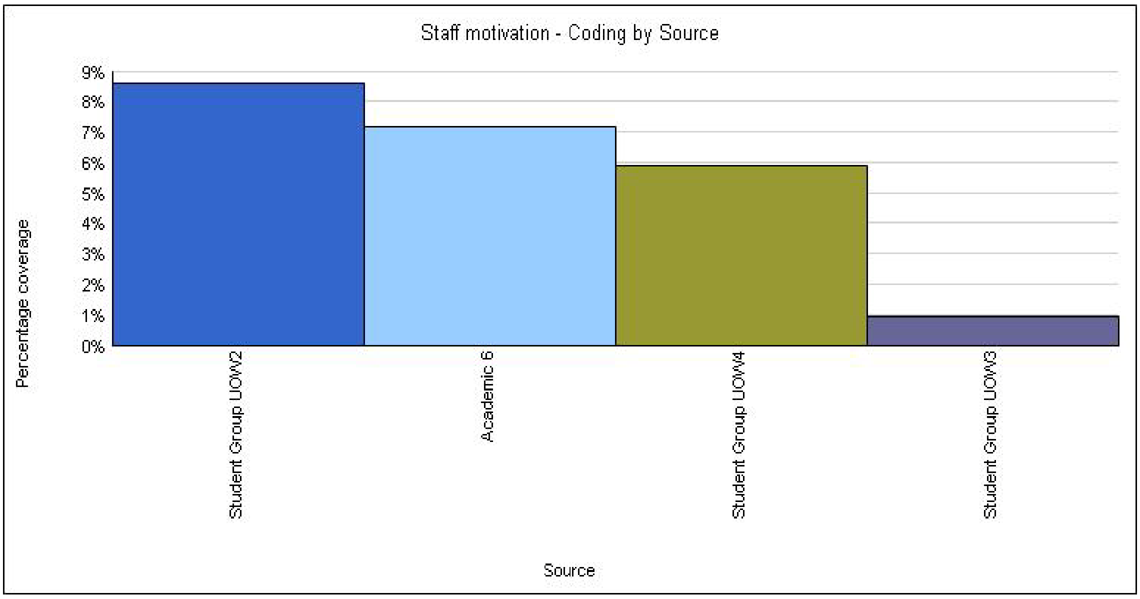


Figure 6.18 Staff motivation free node observed by percentage coverage

The timetabling of ENGG152 (figure 6.19) was mentioned by most participants, although the issue did not spark sustained discussion. It seems that timetabling was only a minor issue, and comments indicated that participants did not believe this was something that needed to be addressed.

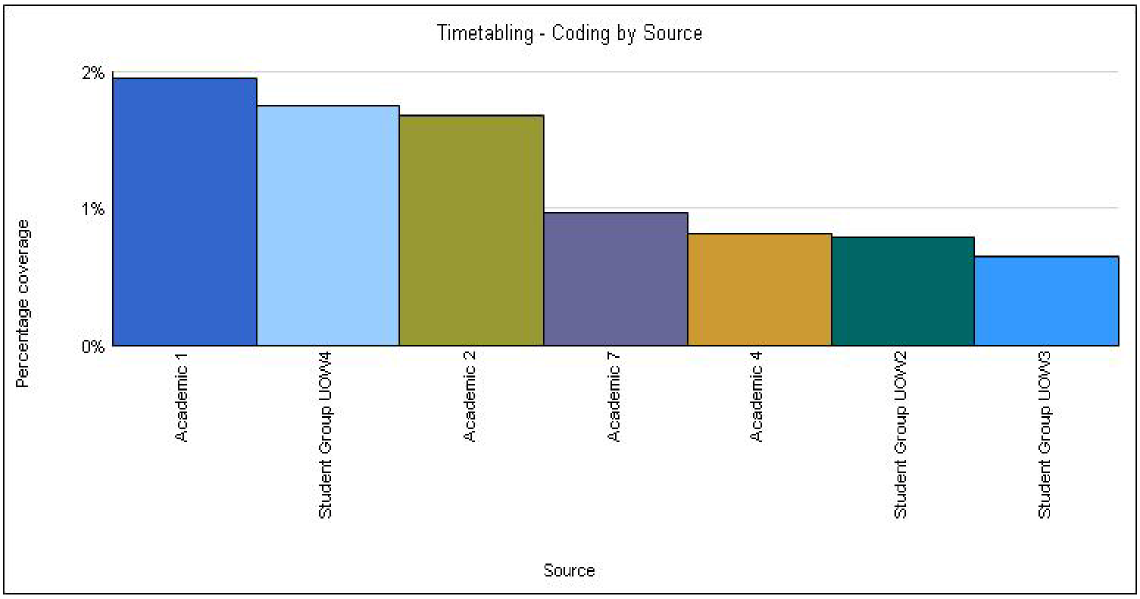


Figure 6.19 Timetabling free node observed by percentage coverage

Finally, Figures 6.20 and 6.21 show the personal comments made by participants in a positive and a negative manner. Such comments relate to individual participants' feelings in regard to a situation or issue, whether they have a positive emotional outcome such as joy, satisfaction, and gratitude, or whether it sparks negative emotions like anger, frustration, and disappointment. These graphs provide a more objective measure of the negative focus of participants comments noted in the first impressions analysis in 6.3. These figures illustrate clearly that emotions expressed when discussing ENGG152 were overwhelmingly negative. At best, student group 1 was slightly more positive than negative, and Academic 4 was only slightly less positive than negative, but the remaining participants expressed a strongly negative outlook on their experience with ENGG152.

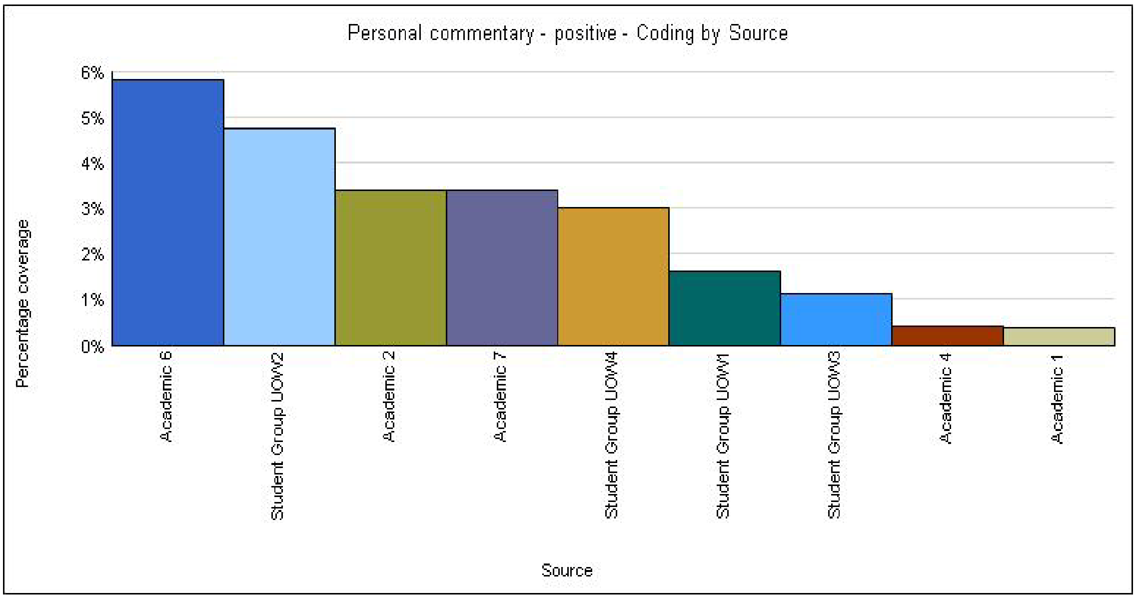


Figure 6.20 Personal commentary – positive free node observed by percentage coverage

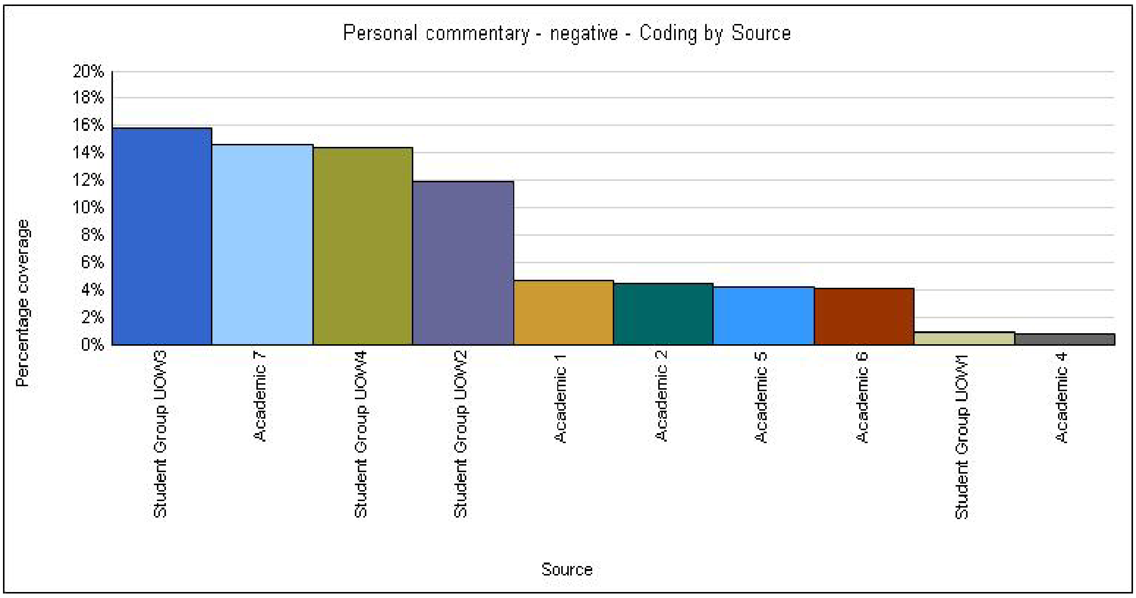


Figure 6.21 Personal commentary – negative free node observed by percentage coverage

6.5 Discussion

After exploring the wide range of views and experiences raised by participants in this study, a picture of the extent of challenges seen by academics and students has been created. The main issues in terms of the nodes established during the analysis are summarised in brief in Table 6.4. This table presents a distilled overview of the many individual concerns raised by participants in this study.

Table 6.4 summary of findings from interviews and focus groups

Node	***Key issues***
Pedagogy	• Mismatch between academics' perceptions of student understanding and students actual understanding – Students continued to struggle with 'similar' questions • Students and staff agreed that out-of-class assignments would benefit learning • Cramming for final exams was common practice and encouraged by the assessment weighting structure • The quiz and exam structure was stressful, students' didn't feel they have time to learn • Disconnect between practical work and the work done in lectures and tutorials – Labs weren't necessarily helping students understand how to solve problems. Students appreciated the intent of practical work though. • Lectures were not engaging, and there was no correspondence between students and staff in regards to effective practices. • Tutors were unhelpful or underprepared. Students' preference for either statics or dynamics could even be swayed by the tutors. • Mismatched expectations between students and staff in relation to who leads the class were resulting in frustrations on both sides. • The need for a close contact tutoring format like pass was noted by all students, but only 2 staff. • Students' views on the helpfulness of textbooks and worked examples were polarised. Students tended to find the textbook difficult to use with limited examples, while lecturers were confident the textbooks contained more than enough examples. • Students viewed close contact with their tutors and lecturers favourably.
Student approaches to study	• Students were working towards assessments only • Competing demands from concurrent subjects were inhibiting deep engagement with the content
Student Motivation	• Some students were only aiming for a pass mark. • Lack of success during study was leading students to give up on understanding the content and focusing instead on just passing.
Course structure	• Statics and Dynamics were seen as two distinct subject areas – this was reinforced by course structure and standard texts • Both students and staff believe the course was overloaded with

	content.
Personal reflection on learning	• Academics own experiences of learning Mechanics were quite different to those of current students. Students appeared to pick up on this in highlighting the disconnection between student and teacher.
Academic history	• Students and staff both believed there was a link between academic history and success in Mechanics. The link may be that there is an advantage from strong academic background, but this is not the only way.
Specific content and content difficulty	• Common themes were curvilinear motion and rotational motion, relative motion, and vector analysis in three dimensions • Aside from the above, there was little consistency in comments on the challenging or less challenging topics. Most comments were phrased in very general terms. The evidence suggests that difficulty experienced by individuals was highly variable – there were no clear 'most challenging' concepts. • Many students were stuck on basic concepts and couldn't progress their understanding
Assigning responsibility	• Staff and students both tended to focus on each other's actions and behaviour more than their own. This may make developing a more partnership-like approach to learning difficult.
Outside influences	• Students concerned with the uni workload distracting from study in 152, academics believed activities outside the university are the main concern.
Content overload	• Content overload was driving students to take surface approaches to learning. • Mechanics education had been overly compressed in recent years.
Staff motivation	• Incidences of unmotivated staff was not recognised by most academic participants, this appeared to be an issue only seen by students
Positivity v. Negativity	• Participant responses were overwhelmingly negative – most participants seemed to hold a negative outlook on the teaching and learning situation in Mechanics.

Referring to the summary of key issues in Table 6.4 gives an overall impression of the learning and teaching experience in the first year Mechanics subject, ENGG152. There are a number of underlying themes that can be seen from this summary, these are discussed in terms of Biggs' 3P model below.

6.5.1 Mismatched student and staff expectations

Students expressed the need for more support through the learning-focused activities and a preference for the tutor or lecturer to take the lead in doing this. This expectation of a teacher centred learning environment is a major issue to be considered in designing engineering Mechanics course, but not one that is likely to be specific to engineering Mechanics. The literature on students' transition to higher education has identified the challenge of student expectations that are mismatched with reality for years (McInnis, James, & McNaught, 1995; Tinto, 1993). This specific issue of students expecting teaching that delivers all the necessary information has also been identified in other contexts (Cook & Leckey, 1999; Felder & Brent, 1996; Symons, 2012). There was clear evidence that students both desire and expect educators to lead learning in the classroom.

In this research, it was clear that these students' expectations of a teacher centred learning environments (or teaching context) were not matched by the opinions expressed by the academics interviewed here. The issue of students opposing, or even resenting the transition to student-centred teaching is discussed by Felder and Brent (Felder & Brent, 1996) in terms of the challenges of transitioning to student-centred teaching approaches. In their paper, Felder and Brent offered strategies for dealing with many of the concerns raised by the academics interviewed here. These include structuring formative assessment tasks around what students are expected to do to clarify their role in the class, and setting up the environment to be entirely student led, with the educator only intervening at key points. However, it was not clear from the subject overview in Chapter 3, nor many of the participants' responses here that academics' teaching Mechanics were aware of the many strategies available for addressing students' apparent dependence on teacher-centred approaches. Student-centred teaching approaches described by academic participants were based on expectations of student autonomy rather than comprehensive curriculum designs with appropriate support mechanisms.

These mismatched expectations appeared to show the impact of poorly understood ‘presage’ factors leading into the ‘process’ of learning. This poor understanding was the case for both students and educators. Biggs’ 3P model suggests that this mismatch may also be leading to student disengagement and surface approaches to learning, such as those that were encouraged by procedural knowledge-focussed assessment approaches (see 4.4). However, Biggs model does seem to imply that presage factors can and should be understood before learning-focussed activities. Participant responses throughout this study suggested that understanding of ‘presage’ factors only occurred during the ‘process’ of learning. Examples of this include students’ understanding of how tutors provided assistance, which differed between individual tutors, and academics’ observations of how students responded to their teaching approaches in comparison with how they thought they would respond. This seemed to indicate that understanding and responding to some factors considered to be part of the ‘presage’ to learning-focussed activities can only realistically happen as part of the ‘process’ of learning.

6.5.2 Assessment driven learning

Student and academic participants were in agreement about the assessment driven approaches to learning Mechanics that are common among students. Once again, this is not something that is considered unique to engineering Mechanics. Other authors have identified this issue and proposed strategies for discouraging this approach to learning (Alpay, et al., 2010; Besterfield-Sacre, et al., 1998), or utilising it through improved assessment design ("Assessment Futures," 2010; Boud, 2010; Ramsden, 1992). The challenge for engineering Mechanics courses may be the traditional quizzes and examinations that form the majority of assessment (see 3.1.1), which encourage last minute study, or ‘cramming’. As shown in Chapter 4, the types of questions used also have a bias towards procedural knowledge which can be memorised through repetition without necessarily understanding the interrelationships between facts or procedures (Romiszowski, 1981, p. 246).

The assessment driven approaches to learning identified here aligned to Biggs representation of the interrelationship between assessment and student motivation in the presage stage of learning. However, what was also clear in this study were students reports of motivation as a result of ‘process’ and ‘product’. Biggs’ 3P model published

in 1999 (J. Biggs, 1999, p.18) does suggest the existence of this relationship, but does not suggest that experiences in learning-focused activities and assessment outcomes are key drivers of motivation as students reported here.

6.5.3 Focus on the small, not the whole

From the academics' and students' comments, there was little evidence that ENGG152 was being considered in a holistic manner. There was an overriding focus on one issue to the next with limited reflection on how each concern relates to the learning experience as a whole. This continues a theme evident in the engineering Mechanics education literature, where previous work to improve learning tended to focus on specific problems in isolation from the course design as a whole (see 2.4).

Students and academics also both tended to focus their discussion of issues in Mechanics education on problems that were seen as beyond their control or responsibility. From the student view, issues around teaching strategies were cited, while academics tended to focus on student factors or other aspects of the teaching context. There was very little extended discussion, from both students and educators, on the effects of their own actions on learning and teaching Mechanics. This may indicate a lack of appreciation of individual responsibility within a holistic understanding of teaching and learning in Mechanics.

This focus on the small also relates to identifying challenging topic areas because the range of problem topics and concepts in the literature (see 2.2.4), the range identified in the analysis of students work in chapter four, and the variability in determining the 'difficulty' of certain concepts shown in chapter three and repeated in participant responses here, all indicate that focussing on particular topics to improve student performance overall will be ineffective. Any approach that seeks to improve Mechanics learning overall will need to accommodate all the topic areas in the Mechanics course. In doing this it is important to consider how the individual is experiencing learning a topic area, rather than how challenging a topic is deemed to be by others (Brookfield, 1990).

Understanding the meaning of this focus on particular issues in absence of a more holistic understanding of Mechanics was a challenge. Biggs 3P model clearly situates many individual elements of the teaching and learning process raised by participants

within a holistic model of teaching and learning. However, the current model does not clearly indicate where individual responsibility may lay, particularly in the process and product stages. Nor does it give a great insight into how individual learning needs might be dealt with.

6.5.4 Critique of analysis

The analysis of results was conducted in two ways: The 'first impressions' analysis, identifying the big issues from a basic review of transcripts and recordings, and the more detailed analysis utilising Nvivo. Some key differences were observed in the two different analysis approaches. The detailed analysis using Nvivo grouped together participants' responses under broad categories referred to as 'nodes'. This allowed for a general focus of participants' responses to be observed <u>before</u> specific comments were considered. Following this, the analysis was drawn down to a more specific discussion on the issues raised using quotes captured within each node.

The first impressions analysis operated in the reverse order in that it focused immediately on specific instances as a way of identifying and discussing broader themes. In the process, some of the underlying themes identified in the Nvivo analysis were missed. This outcome could provide some insight into why participants' responses were so varied in some cases, and why particular issues highlighted in Mechanics by individuals don't translate into general learning improvements when addressed (Chapter 2). In many cases literature sources and participants cited cases to explain what is thought to be a wider issue without sufficient evidence to confirm that it is in fact a wider issue. The detailed analysis conducted here with the aid of Nvivo was able to determine whether issues raised by individual participants were related to those raised by other participants, and subsequently a broader theme. So it may be the case that the first impressions analysis was indicative of the process by which participants arrived at the conclusions they raised during the interviews and focus groups. Would the outcomes of this research look different if the participants themselves had each surveyed the situation objectively before taking part in the interviews? Had participants looked at particular issues on balance, would they have a more positive outlook on the subject, or an even more negative one?

One of the themes apparent from both methods of analysis was the focus on the negative among most participants. While it is understood that this was most likely an

effect of the participant's experience of ENGG152, the influence of the interview and focus group prompts was considered further. The orientation of the questions, whether they were framed positively or negatively, could have impacted on the way the participants responded. Tables 6.5 and 6.6 revisit the questions set and present judgments on whether they were framed positively or negatively.

Table 6.5 Positive/negative orientation of focus group question set

Question	***Orientation***
What don't you like about any aspect of the course? Exams, lectures, tutorials, labs, staff etc.	Negative
What do you like about the course?	Positive
Is there anything you would like done differently from your experience so far?	Neutral
Are there any particular topics you find more difficult than others?	Negative
Do you prefer lectures/tutes/labs as a teaching mode? Why?	Positive
How much study time to you think is fair for a course like this? Would you do this amount regularly?	Neutral
Are there any factors other than the course itself that you think might make study harder?	Negative
How do you think subjects/education you took before ENGG152 have affected your learning?	Neutral
How do you think you will go in the subject overall? Would you be happy with this?	Neutral

Table 6.6 Positive/negative orientation of Staff interview question set

Question	***Orientation***
What do you students appear to like most about the course?	Positive
Are there any particular aspects that student seem to dislike about engineering Mechanics (more than usual)?	Negative
Which topics do students seem to find more difficult than others?	Negative
What sorts of things have been tried to improve learning in Mechanics? What was the rationale?	Positive
What teaching modes do students appear to prefer? Why might this be?	Positive
What impact do you think academic history has on learning? Which aspects in particular?	Neutral
How much study time to you think is fair for a course like this? Do you think students do this amount regularly?	Neutral
Have you ever had complaints from students that the subject is too hard/easy?	Negative
Are there any factors other than the course itself that you think might have a negative effect on learning?	Negative

The ratio of positive to negative questions in the student focus group set was 2:3 and for the Academic interview set, 3:4. So there was a slight bias toward negative questioning that could have influenced the way in which participants framed their responses. The extent to which this influenced participants' responses is difficult to determine with confidence. However, it was apparent from the participant responses that although positives about ENGG152 were identified with direct questioning, participants did not tend to elaborate on these to the extent to which negatives were explained. This is supported in the comparison between positive and negative commentary in figures 6.20 and 6.21, which indicated that positive commentary was made in all sessions, but had smaller percentage coverage across all participant groups. Other factors such as the motivations of the self selected student participants, the academic culture around critique and the pursuit of improvement, and the manner of the interviewer/facilitator during the sessions could all have also influenced this outcome. What was important to

consider here is that any attempts to improve Mechanics education would need to take into account the potential for strong critique and a negative outlook from students and academics.

6.6 Chapter Summary

The outcomes of this qualitative study provided significant insights into the teaching and learning practices that were common in first year Mechanics at the time of the study. The results of this qualitative research highlighted several key issues in Mechanics teaching and learning, including:

- Mismatched student and staff expectations around teaching, learning and assessment;
- Assessment driven approaches to learning;
- A focus among students and staff on specific issues and incidents in the teaching and learning which are considered in isolation from the educational experience in Mechanics as a whole; and,
- An apparently negative outlook on the teaching and learning experience in Mechanics among students and staff.

These outcomes, combined with the outcomes of the analysis of the examination paper in chapter four and the statistics on students' academic background also confirmed that various factors such as student approaches to study, motivations and learning needs varied from person to person. However, the views and experiences reported from the interviews and focus groups only related to teaching contexts and learning-focused activities that participants had previously experienced. Subsequently, students' and academics' suggestions on how to improve Mechanics education revolved around these familiar educational approaches and resources.

The review of engineering education literature in chapter two identified previous studies of innovative web-based learning resources in Mechanics which had delivered small, but measured improvements in student achievement in assessments (see 2.3.1). In addition, many of these online learning resources were already available online for use by students at no cost (Hadgraft, 2010). More needed to be understood about how these

alternative approaches to Mechanics education could be utilised to improve learning in Mechanics. More importantly, how students engage with and respond to these new resources when they already have access to the more traditional approaches used in ENGG152, would provide insight into the potential for online learning in comparison to existing teaching approaches. This is examined in chapter 7.

Chapter 7
Online, independent learning

7.1 Introduction

The qualitative research in the preceding chapter identified several major concerns held by students and staff. When asked how to improve learning in Mechanics, participants all tended to focus on refinements to current practices, or familiar approaches that had been implemented in other subjects. None of the participants referred to one of the major areas of research in Mechanics education – online and computer aided learning – as a possible way forward for Mechanics education. Numerous authors have developed, implemented, and evaluated online learning with some positive indications of success reported (Philpot, et al., 2005; Prusty, Ho, & Ho, 2009; Prusty, et al., 2011; P. Steif & Dollár, 2009). The potential for sharing these resources to provide a range of possibilities for supporting learning in Mechanics has also been highlighted (Hadgraft, 2007, 2010; Prusty, et al., 2011).

To this point of the research, investigations had revolved around current practices in Mechanics education at UOW, UTAS, UTS, and AMC. Before drawing the evidence from these investigations together, it was necessary to explore the potential of online learning for improving Mechanics education within these contexts. In 2010, an online database of existing, and freely available Mechanics online learning resources was created as an outcome of an Australian Learning and Teaching Council funded project. The database, learnmechanics.org, allowed students to search and access a variety of learning resources relevant to engineering Mechanics. The intention behind the development of the database was to provide students with alternative tools for studying Mechanics, in addition to the existing support at university (Goldfinch, et al., 2010; Goldfinch & Gardner, 2010).

The database was used in this research as a tool for understanding how current first year Mechanics students at UOW might engage with alternative options for learning. By targeting UOW students studying in ENGG152, the findings of this component of the research could be compared to those of previous chapters. This was not intended to be an exhaustive study of online learning resources in Mechanics. It was instead intended to provide a contrast to the investigation of existing curricula presented in preceding

chapters. This component of the research also explores an issue raised during the review of literature on online learning in Mechanics. The issue is that these resources, implemented as compulsory out of class study, may simply be enforcing more repetition of typical problems as opposed to deepening students' engagement with Mechanics concepts.

7.1.1 Overview of the Mechanics learning resource online database

The research described in this chapter focuses on the student participants' interaction with the learnmechanics.org site and other learning resources, rather than evaluation of the site or resources themselves. This section provides a background to the structure and functionality of the learnmechanics.org site for context. This brief description of the learnmechanics.org resource database was adapted from two papers published upon the establishment of the website in 2010 (Goldfinch, et al., 2010; Goldfinch & Gardner, 2010).

The content of the database evolved from a list of online Mechanics learning resources published on the AAEE-Scholar Wiki (Hadgraft, 2010). The resources listed on this site were the more complete, online course style resources. In addition to this style of learning resource, the creation of very brief, topic specific learning resources has also gained some momentum (Porter, Baharun, & Algarni, 2009). For example, a 2009 thesis study at the University of Wollongong led to the creation and evaluation of a set of 3-5 minute tutorial videos created using a Tablet PC. These videos covered 3D vector analysis of static problems, with some positive results reported in terms of student feedback (Burrows, 2009). Adding many brief, single topic resources such as these to a simple list of recommended resources, as was done by Hadgraft (2010), would quickly extend the list to a point where finding resources would become difficult.

The learnmechanics.org database was created to allow for the inclusion of numerous small resources. With so many different resources available, it was necessary to develop a method of evaluating and summarising the content and format of resources. A similar online database of learning resources, merlot.org, used a very simple set of metadata to categorise resources: general technical information, a resource summary, author details, target audience etc. Resources on this site were also organized into study discipline areas (MERLOT, 2009). As the learnmechanics.org database was to focus on only one area of study, a greater level of detail in the resource evaluation criteria could be

included. The evaluation criteria for resources included in learnmechanics.org are described in Table 7.1.

Table 7.1 Summarised learning resource evaluation criteria

Criterion	***Purpose***
Topics covered	Basic list of topics contained in the resource to simplify searches
Depth of coverage	Very detailed resources are great for beginners, but can be tedious for more advanced students, just as topics that rely on assumed knowledge can be useless for beginners. Three levels were included for this criterion: Focus topics + detailed coverage of fundamentals; Focus topics + coverage of some fundamentals; Focus topics only.
Learning styles catered for	This criterion was based on the learning styles framework by Felder and Silverman (1988). The purpose of including this was to help academics to refer students to a variety of resources in terms of the learning styles they cater for, or for particularly motivated students to ensure diversity in the resources they select.
Type of knowledge emphasized	This criterion was derived from the knowledge types identified in chapter 4. Some resources were developed purely for conceptual understanding, others were focused more on procedures for problem solving, while many aimed for a balance between the two. Three options were considered here: Procedural knowledge, conceptual knowledge, or a combination of the two.
Suitable study patterns	This criterion identified what study context resources were more suited to: independent study, group/peer assisted study, or lecture/tutorial materials for in-class use.
Appropriate learner level	Identified what level of competence students need to make use of the resource. Students struggling to understanding basic concepts may be looking for different materials to students who think they understand the concept and are looking to test their understanding. From this perspective the resources were classified according to five levels: pre-university, just starting the topic, practicing/reinforcing class work, revising, or advanced.

Feedback given	Feedback provided by resources tended to vary in detail, while non-interactive resources, such as video tutorials, give no feedback at all. Details were recorded here in regards to what type and extent of feedback was provided by the resource.
External review	This section identified whether or not resources had been the subject of some form of peer review process or not. Many of the resources available had been the subject of research with associated peer reviewed publications. This could help academics decide whether or not to seek permission to include resources in their course materials, or to recommend them to students.

The learnmechanics.org database and search functions were developed around this evaluation method. There were two search functions on the site. A basic search could be seen after users log in, and was intended for looking up resources that users were already aware of. For example, if a student knew the name or author of a resource recommended by a peer, they could simply search for either of these and find the resource quickly. For users looking for new resources, there was an advanced search option (see figure 7.1). This advanced search option allowed users to search only for a particular topic area, or they could further refine the search with a range of options adapted from the evaluation criteria in table 7.1. Search results were listed in order of relevance, with resource name, authors, and a brief description displayed. As an alternative to searching, all resources are displayed by default, allowing users to simply browse through a list instead.

Figure 7.1 Advanced search screenshot

Decisions on what Mechanics learning resources to include on learnmechanics.org were made so as to encourage students to keep using the site, and avoiding including anything that may discourage them. There were three main aspects considered here:

1. Does it cost? Online learning resources were selected for inclusion in the database on the basis that they were available for students to use in independent study free of charge. It was assumed that students would be unlikely to continue using the database if they were repeatedly required to pay money for access to resources.

2. User friendliness. Resources that could be understood through trial and error or very brief instructions were prioritised because they were likely to be more appealing to students who are going out of their way to investigate new learning options (Feiertag & Berge, 2008).

3. Duration. A number of resources identified were simply videos of entire lectures previously posted online. While some students may find these lectures useful, it was concluded, based on the attendance rates, that few students would be willing to watch a 60 minute video clip online. Only video resources under 10 minutes were included at the time this research was conducted.

The site didn’t actually host learning resources. It was set up to direct users to resources hosted elsewhere on web. The site also required users to sign up and log in before they

could start using it (see Figure 7.2). The purpose of this is was to monitor what sorts of users are utilising the site, how many people were using it, and whether or not people visited repeatedly. This data was utilised in the research covered and discussed in this chapter.

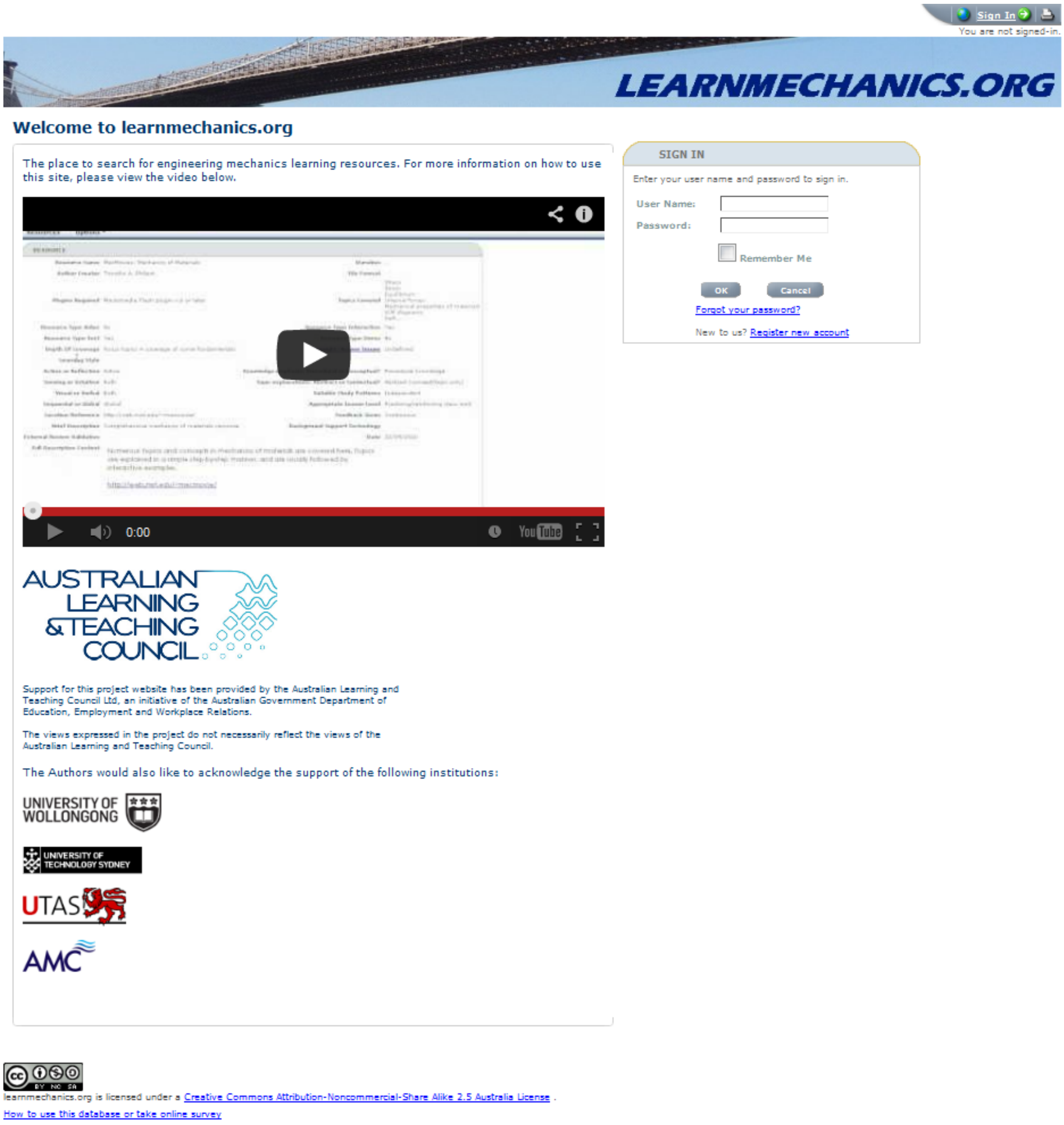


Figure 7.2 learnmechanics.org welcome and login screen

7.2 Method

The research approach used in this evaluation of students' engagement with online resources was similar to the combined video observation-think aloud method utilised by

Litzinger et al (2010) and Taraban et al (2011). These studies used video observations to capture the process of problem solving in Mechanics rather than only the outcome. The priority for the observations in the current research was to observe how students approach and interact with alternative learning resources. Determining the effect of this interaction on final grades was outside the scope of this research.

Participants in this research were first year undergraduate engineering students enrolled in ENGG152 engineering Mechanics at UOW in 2010. The research was conducted approximately two thirds of the way through the teaching semester. This allowed enough time for students to have completed a number of course assessments and be considering their final examination. Although this research was conducted in 2010, there were no changes to the subject from the 2008 year used in the preceding chapters. The research involved self selected participants in both individual (single participant), and group (multiple participant) settings. In total, three individual participant sessions and one multiple participant session were conducted at UOW. While this represents a very small sample, the goal was to explore the potential of online resources in contrast with other teaching modes in ENGG152 that were discussed previously.

To recruit participants, the research was presented as an opportunity to receive extra assistance with study in Mechanics. Aside from access to this learning resource, participants were offered a one-on-one tutoring session after participating in the research. Participants in the study were a mix of high and low achieving students and included two mature age students, one female student, and one international student. The participants represented a varied cross section of the student cohort (though not a statistically representative sample).

This research used three modes of data collection, see Figure 7.1. A preliminary interview was conducted with each participant or group of participants to determine the topics they were having difficulty with, and their preferred approaches to teaching or study. These interviews were semi-structured and were 10-15 minutes in duration. Participants were free to express issues important to them. These interviews were recorded by freeform written notes to generate a simple recording of the key issues raised by students, and some interesting quotes. These notes formed the background to the analysis of participants' engagement with the database, as depicted in Figure 7.3.

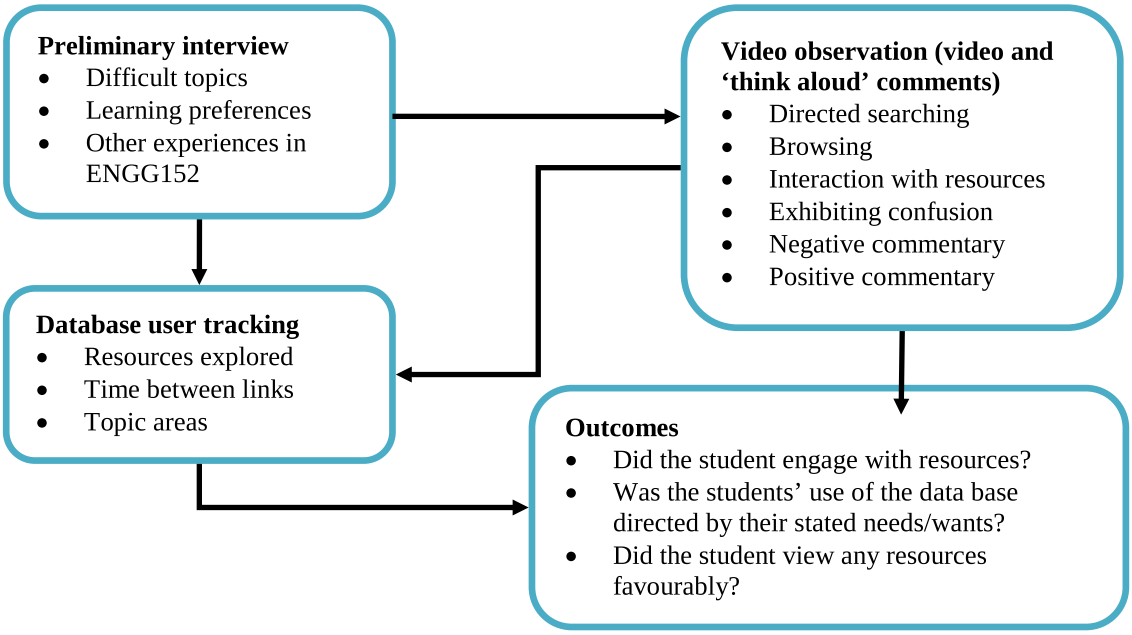


Figure 7.3 Schematic representation of the evaluation of students interaction with online Mechanics learning resources.

The interviews were followed by a 30-45 minute session using the learnmechanics.org website, although a number of participants voluntarily explored the site for up to 60 minutes. Participants were asked to provide verbal commentary on the online Mechanics learning resources they accessed and the learnmechanics.org site itself whilst being video recorded. For single participants the video camera was directed to focus on the computer screen only to capture the students interaction with resources in detail. For the multiple participant session, the camera was positioned to capture two of the three screens in use. All sound was captured in the multiple participant session.

During the student focus groups evaluated in the previous chapter, most participants had difficulty identifying and describing challenging topics without referring to course outlines. To address this issue in the observation sessions, participants were given access to previous weeks' tutorial questions. These were provided to help students quickly identify the areas they had difficulty with, and to direct their search accordingly if they chose to.

Video recordings were then analysed in Nvivo 8. In contrast to the qualitative research described in Chapter six, nodes were developed using an inductive approach. This approach was made possible by the lessons learned in previous research and the more focused nature of this research. As can be seen in Figure 7.1, the video observations of

students using learnmechanics.org sought to determine how effectively they engaged with the selection of resources. The nodes defined for the analysis, and their purpose are described below.

***Directed searching* –** instances where students were either using the search functions of the site, or purposefully browsing the list for appropriate resources.

***Browsing* –** Instances where students were browsing content without a clear purpose or aim.

***Interaction with resources* –** instances where participants were engaging with resources. These included reading content, trying interactive tools, using information from resources to solve tutorial problems.

***Exhibiting confusion* –** instances where participants demonstrated uncertainty or confusion about the learnmechanics.org site itself or any Mechanics learning resources. Instances of confusion were identified through participants' comments as they navigated, or by the nature of requests for assistance from the facilitator.

***Positive commentary* –** comments made by participants that reflected positively on the database or any learning resources.

***Negative commentary* –** comments made by participants that reflected negatively on the database or any learning resources.

***Content suggestions* –** Suggestions made by participants on what they would like to see in the database

***Guided searching* –** Searches directed by the facilitator from requests or queries made by participants

Finally, the usage statistics recorded by the learnmechanics.org site were downloaded to track which learning resources students had accessed. This was a particularly important dimension of the study for the multiple participant sessions where sites accessed by students were not clearly visible on the video recording, or if a students' screen was not in frame. The usage statistics also recorded the time each link was clicked by the participant, from which the time participants spent looking at resources could be

estimated. It was also possible identify whether any of the participants from the sessions accessed the database after the conclusion of the observation session.

The research described in this chapter was approved by the UOW Human Research Ethics Committee, approval number HE10/318 (see appendix F for letter of approval, participant information sheet, and consent form).

7.3 Results

The results are presented here for each observation session. The events coded in Nvivo 8 (QSR, 2008) were compared to the initial interview and the database user tracking.

7.3.1 Student 1

In the preliminary interview, student 1 expressed that ENGG152 was a challenge, but that he was not having any trouble with the three other subjects he was enrolled in during that semester. The only particular problem topics noted by student 1 were some initial concerns about the relationship between displacement, velocity, and acceleration in dynamics. Student 1 described dynamics as “a way of thinking” that he found challenging. This student was also working from an older edition of the prescribed text which caused occasional problems in class, however, most of his negative comments related to the tutors themselves. The student had different tutors for the dynamics and statics components of the course, and found the statics tutor very unhelpful. Student 1 did note, however, that his perception of tutor quality was not reflected in his quiz marks.

Overall, this student had some complaints and had experienced some difficulty. While he appeared to like Mechanics and was progressing at pass level, he expressed some anxiety about the final examination. This student’s comments and self reported ability appeared to be similar to a number of participants in the focus groups discussed in the previous chapter.

The coding results for the video observation are presented below in two different manners. Figure 7.4 shows the number of separate instances in which a particular event occurred, Figure 7.5 presents the same coding according to the total duration of the events. Table 7.2 contains the recorded uses of the database during and shortly after the observation session.

Both Figure 7.4 and 7.5 show that student 1 only browsed the learnmechanics.org, the search functions were not utilised and there did not appear to be any purposeful manual search for specific resources. Student 1 interacted with four different resources for a significant amount of time during the session, with resource interaction taking up the bulk of the session. Table 7.2 shows that several different resources were accessed during the session, all of which related to Statics. This was not aligned with the difficulties mentioned by the student in the preliminary interview. However, it does reflect the comments relating to his statics tutor. Student 1 was unique among the participants in returning to the learnmechanics.org site in the days following the observation session on two occasions. This is an indication that the student found the site and the resources linked to it useful enough to spend more time on them. Student 1 had some difficulty using the site and the resources, exhibiting confusion on four occasions (Fig 7.4), Fig. 7.5 indicates that this confusion was short lived.

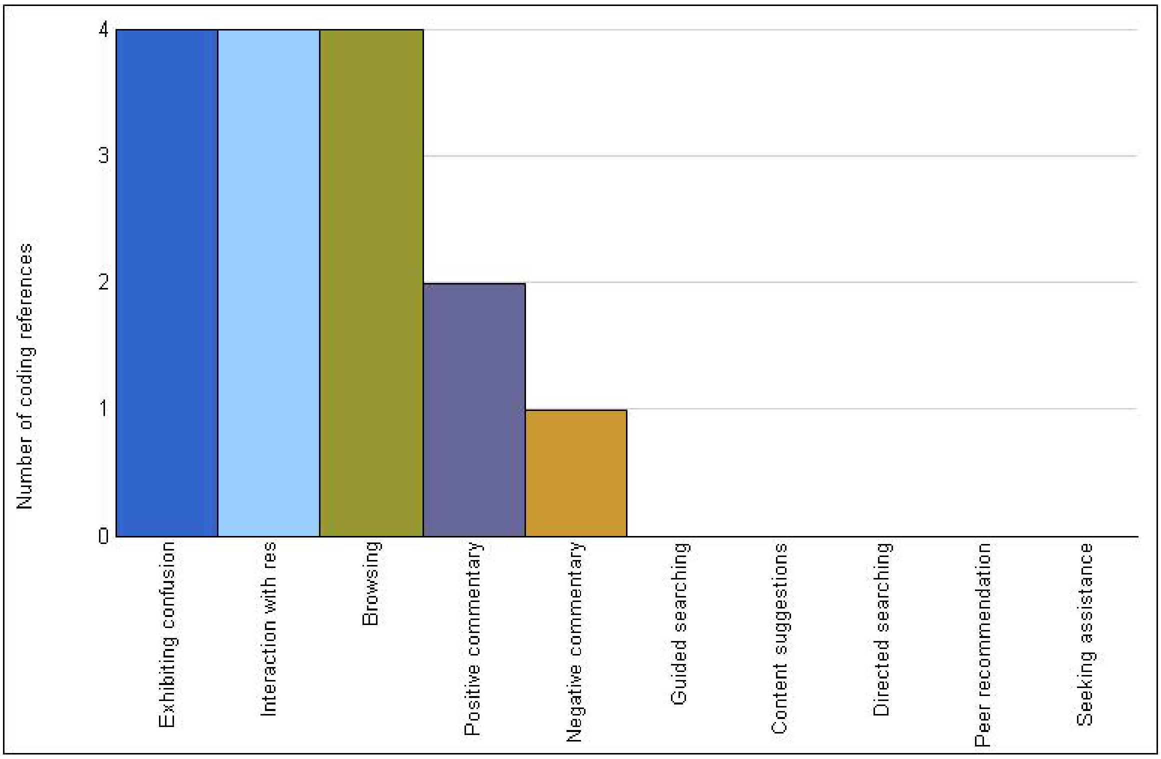


Figure 7.4 Number of instances coded to each node for Student 1

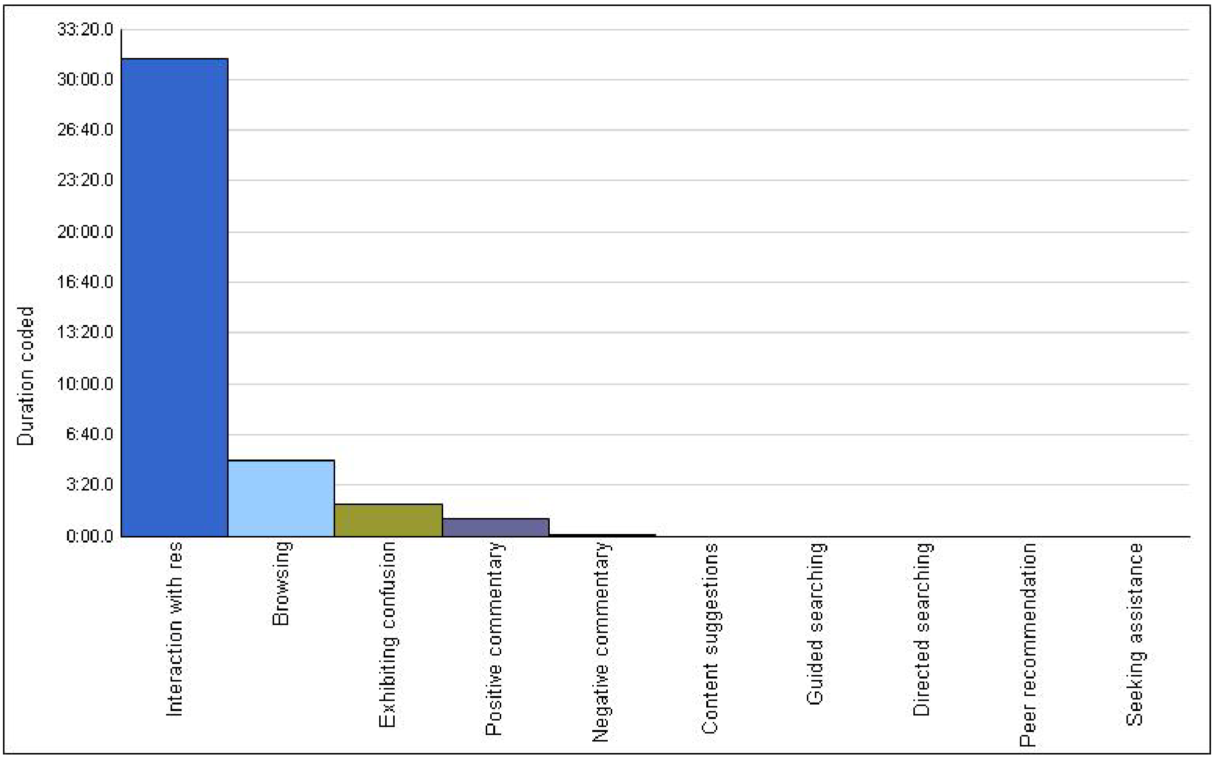


Figure 7.5 Duration of all instances coded to each node for Student 1

There appeared to be no strategic or directed approach to searching out resources, with Student 1 tending to browse through and try out different resources. This was also evident in the brief time intervals between different resources in table 7.2. During the session there was no evidence of directed or guided searching, or seeking assistance with problems or the learning resources themselves. This could have been related to Student 1's self reported experience in ENGG152. This student noted that the subject was challenging, but did not pinpoint particular topics that he was unable to comprehend. In terms of commentary, Student 1 commented on only three occasions. Two of these comments were positive and were related to online resources dealing with vectors. The single negative comment related to the user interface of the database. Throughout the session, student 1 did not refer to the tutorial problems provided.

At the conclusion of the observation session, the student did request assistance from the researcher on a number of issues identified from the learning resources. Notes retained from the problems discussed at this point indicated that component vectors and acceleration/velocity/displacement graphs were the cause of his confusion. There were resources available through the database that could support these problems. A number of these were accessed by student 1 during the session: eCourses:Statics and Open learning Initiative: Engineering Statics. Table 7.2 shows that the Open learning

initiative resource and eCourses:dynamics these were subsequently accessed after the observation session, suggesting that the student saw some benefit in utilising the online learning resources during independent study.

Table 7.2 resources accessed via the learnmechanics.org site

Resource	***Date***	***Time***
Self Assessment: Structural Analysis I	28/09/2010	2:40:37 PM
Self Assessment: Structural Analysis I	28/09/2010	2:41:38 PM
eCourses: Statics	28/09/2010	2:55:50 PM
MecMovies: Statics	28/09/2010	2:56:50 PM
Self Assessment: Structural Analysis I	28/09/2010	3:09:05 PM
Self Assessment: Structural Analysis I	28/09/2010	3:09:20 PM
Open Learning Initiative: Engineering Statics	28/09/2010	3:09:34 PM
Self Assessment: Structural Analysis I	28/09/2010	3:18:55 PM
Self Assessment: Structural Analysis I	28/09/2010	5:10:04 PM
Open Learning Initiative: Engineering Statics	29/09/2010	12:15:44 PM
Cross Product Tutorials	29/09/2010	12:21:14 PM
eCourses: Dynamics	30/09/2010	2:02:23 PM
Open Learning Initiative: Engineering Statics	30/09/2010	2:03:53 PM

7.3.2 Student 2

Student 2's account of his performance and issues encountered in ENGG152 was far more detailed than Student 1's. Student 2 was a mature age student and noted being disadvantaged in terms of his background in mathematics. Student 2 was undertaking the university mathematics course normally taken prior to ENGG152 a semester late. As a result, he was undertaking this course concurrently with ENGG152. Student 2 commented that he had been putting in a lot of work to catch up on the mathematics content, and he had been successful in achieving this despite the difficulty of the subject. Student 2 went on to comment at length about the study habits of school leavers and how for these students 'the real world's an abstract concept'. This attitude towards

study and reflection on the approaches taken by other students suggested that Student 2 was dedicated to performing well in Mechanics. Detailed comments were also made on the tutors and lecturers and the format of the subject, with a mix of positives and negatives discussed. These comments were similar to those raised by students in previous focus groups, and indicated that problems noted by students two years previously were still an issue in 2010. Student 2 did not comment on particular problem topics aside from mathematics. He noted that none of the content was easy and that there are seemingly simple concepts such as projectile motion that become difficult in application. This suggests that student 2 was also experiencing troubles in the area of procedural knowledge, at least in the way typical Mechanics problems need to be solved.

Figure 7.6 illustrates that student 2 was quite critical of the learnmechanics.org site and various learning resources in a similar way to the pedagogy and curriculum of ENGG152. Commentary and suggestions as to what should be included in the learnmechanics.org site dominated the session in terms of the number of instances recorded. Figure 7.7 shows that the number of instances did not directly translate to time spent making these comments, however, the durations here were still larger than for other participants. This critical mindset indicated to the researcher that student 2 may have already developed study approaches he had found to be successful. This was in contrast to student 1, who engaged at length with the database and resources with very little critical comment.

Student 2 also did not exhibit any directed searching or seeking of assistance. Some brief guided searching was provided following comments on particular resources as the participant was familiarising himself with the site. Student 2 mostly opted to browse the database and resources, stopping to interact with only one at length. As table 7.3 shows, the variety of resources browsed did not exhibit any purposeful searching of resources. This is in line with the interview outcomes as student 2 did not express any specific learning needs. Student 2 also did not seek assistance during the session or at the end of the session as student 1 did. He did not access the database after the observation session either.

Overall, the researcher concluded that this student did not find the database or the learning resources linked from it useful. His critique of the database itself and several of

the resources suggested that this approach was not seen as a useful addition to the study approaches student 2 had already developed.

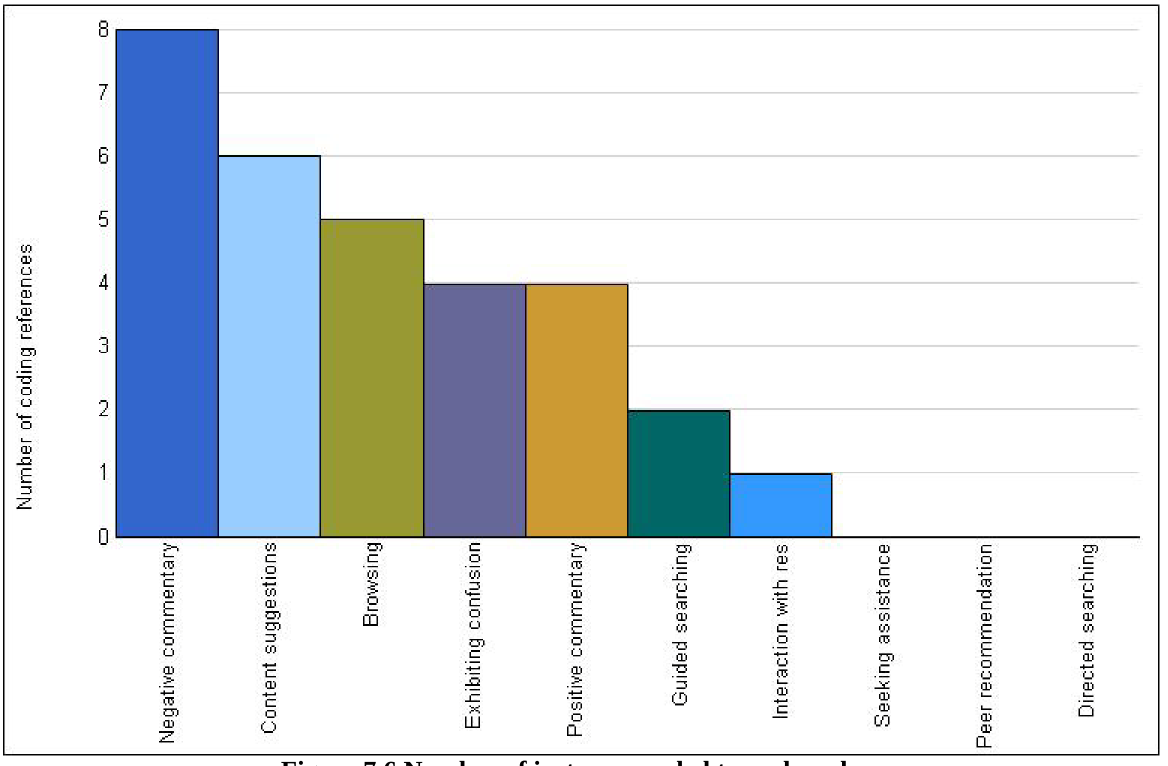


Figure 7.6 Number of instances coded to each node

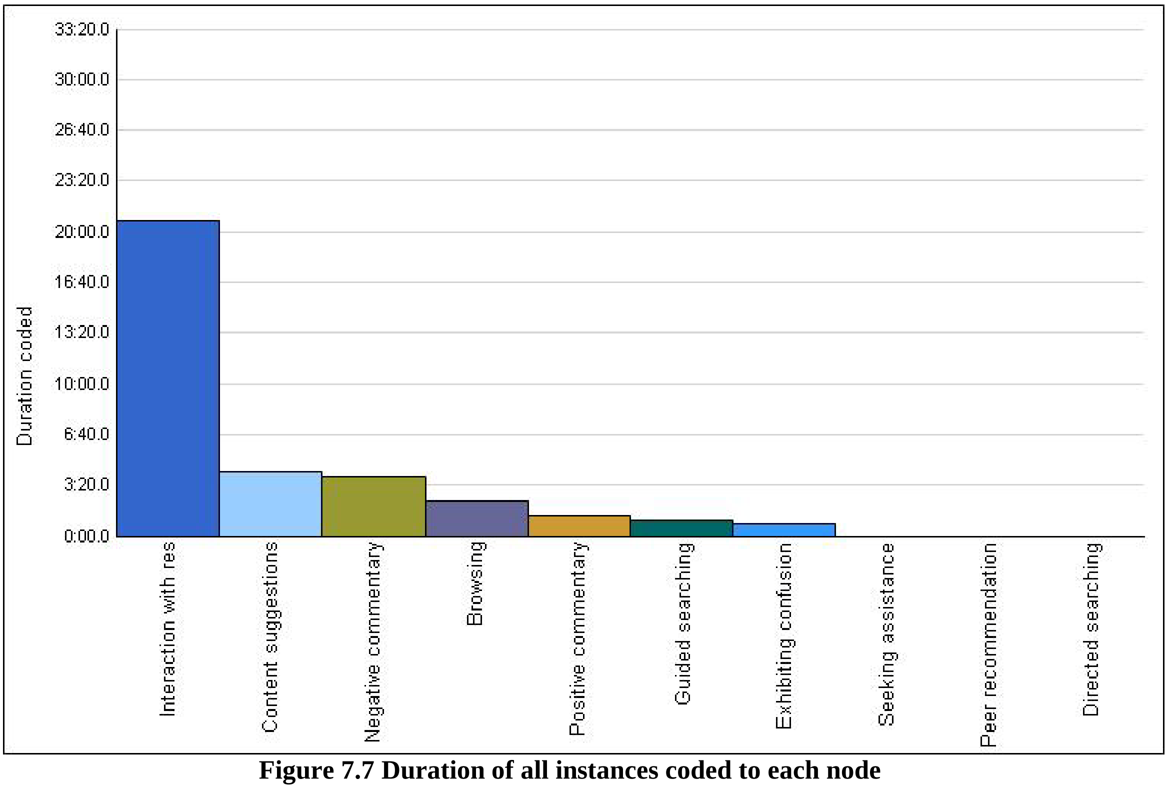


Figure 7.7 Duration of all instances coded to each node

Table 7.3 resources accessed via the learnmechanics.org site

Resource	***Date***	***Time***
MecMovies: Mechanics of Materials	19/10/2010	10:17:44 AM
MecMovies: Mechanics of Materials	19/10/2010	10:20:01 AM
Cross Product Tutorials	19/10/2010	10:51:43 AM
Self Assessment: Structural Analysis I	19/10/2010	10:52:46 AM
MIT Open Courseware: Mechanics & Materials I	19/10/2010	10:53:06 AM
Engineering Dynamics Self Assessment	19/10/2010	10:53:17 AM
Self Assessment: Structural Analysis I	19/10/2010	10:58:23 AM
MecMovies: Mechanics of Materials	19/10/2010	10:59:21 AM
Dot Product Tutorials	19/10/2010	10:59:53 AM
MecMovies: Mechanics of Materials	19/10/2010	11:01:43 AM
MecMovies: Mechanics of Materials	19/10/2010	11:04:59 AM
MecMovies: Mechanics of Materials	19/10/2010	10:17:44 AM
MecMovies: Mechanics of Materials	19/10/2010	10:20:01 AM

7.3.3 Student 3

Student 3, also a mature age student, was succinct and direct with comments on his experience with ENGG152. He remarked that Mechanics had not been too difficult apart from some problems with three dimensional vectors, a common area of difficulty identified in the exam analysis in chapter 4. Difficulties identifying relevant concepts when solving problems were also mentioned. In particular, this student had some difficulty understanding displacement, velocity and acceleration, and the distinction between the conservation of energy and conservation of momentum. Student 3 had some prior experience with Mechanics from high school. He was not satisfied with the level of support from his dynamics tutor, however, whereas the statics tutor was seen as helpful and interactive in their teaching style. Student 3 regularly sought assistance outside class through Peer Assisted Study Sessions (PASS) and from the lecturers.

The analysis of the video recording, illustrated in Figure 7.8, indicated that like the other mature age student in this study, Student 3 was critical during the session. Most of these critical comments were directed towards the learnmechanics.org user interface. These comments seemed to stem from this participant's experience in web page design.

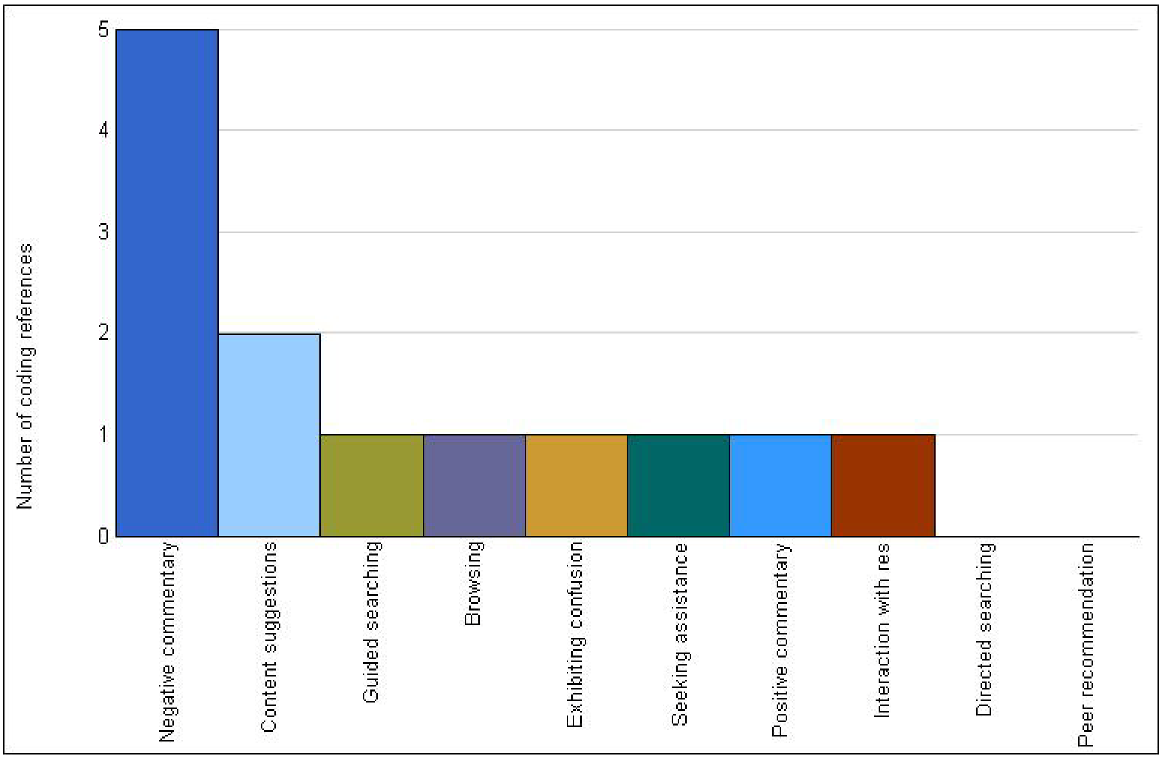


Figure 7.8 Number of instances coded to each node

In terms of engaging with learning resources, very few instances were recorded. As figures 7.8 and 7.9 illustrate, student 3 interacted with only one resource at length during the session, with the other two resources accessed (see table 7.4) only browsed briefly. Although no directed searching was apparent, the resources student 3 chose to browse or interact with were related to problem topics identified in the preliminary interview. This approach to utilising the resources reflected comments and content suggestions made by this participant. These comments indicated that student 3 was quite discerning and informed when it came to independent study.

In the end, student three expressed that the learnmechanics.org site would probably not be useful to him, and that he was likely to continue on with the study approaches that had proven to be effective already.

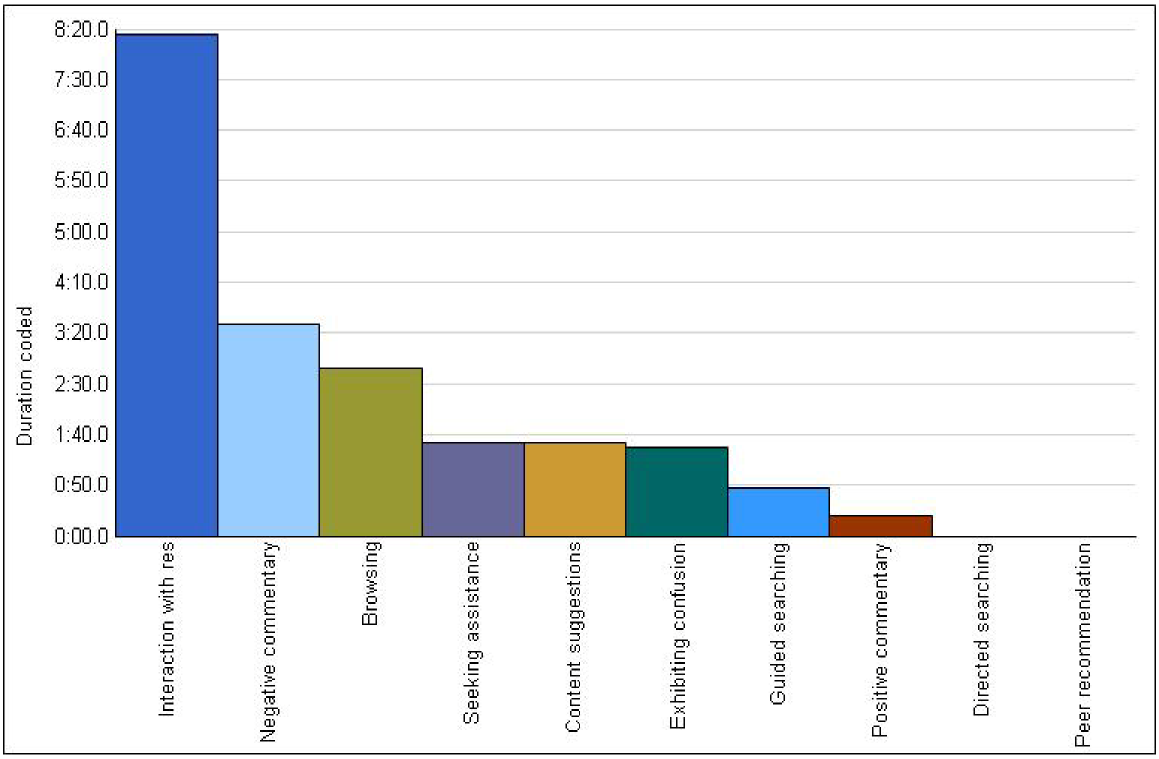


Figure 7.9 Duration of all instances coded to each node

Table 7.4 resources accessed via the learnmechanics.org site

Resource	*Date*	*Time*
eCourses: Dynamics	6/10/2010	4:48:58 PM
Cross Product Tutorials	6/10/2010	4:51:25 PM
Cross Product Tutorials	6/10/2010	5:05:59 PM
Physics Animations	6/10/2010	5:16:56 PM

7.3.4 Group 1

Group 1 was a group of four (three male, one female) school leavers who regularly studied together, were in the same ENGG152 tutorial classes and had completed group assignments. The members of this group reported achieving varying results in ENGG152, but were all passing the subject overall. Pinpointing the difficult topics among the group members was challenging, the only topics mentioned were truss analysis and tangential/normal acceleration, and more broadly, statics was regarded as being easier than dynamics. Most of the participants comments in the preliminary

interview focused on the running of the subject and tutor quality. Like the other three participants, students in Group 1 all compared their statics and dynamics tutors. In this case they each considered their statics tutor to be more helpful than their dynamics tutor. Like Student 3, the members of this group considered their PASS class mentor to be particularly helpful. The group noted that lectures were also helpful because the lecturers regularly presented worked solutions.

Accurately coding all instances against each node in this session, and in the remaining group sessions proved difficult as there were several events occurring simultaneously and not all screens were in view. The results presented in Figures 7.10 and 7.11 represent a conservative approach to coding. Only instances which were clear and distinct in the recordings were coded, meaning more instances in each node were likely to have occurred. The coding results for the group sessions should be interpreted as 'at least X no. of instances occurred for node Y' and 'at least X minutes were spent by participants in relation to node Y'. The tables, however, are precise, and where more than one participant was working from one computer, this is noted in the user column in table 7.5.

A quite different approach to engaging with the site was apparent with this group compared to individual students. As was immediately apparent in Figure 7.10, the participants frequently sought assistance from each other and requested assistance from the facilitator. There were also numerous instances of directed searching (from other participants) and resource interaction as a result of this assistance. After a brief period of browsing and exploring the site, the attention of participants in this group turned to focus on the topics for the current weeks' lecture and tutorial class. It can be seen in table 7.5 that the participants all accessed the eCourses: Dynamics online resources to search for information on impact analysis, the key topic for that particular week in ENGG152. The collaborative approach taken by this group appears to have resulted in a more productive and focused interaction with the database and learning resources.

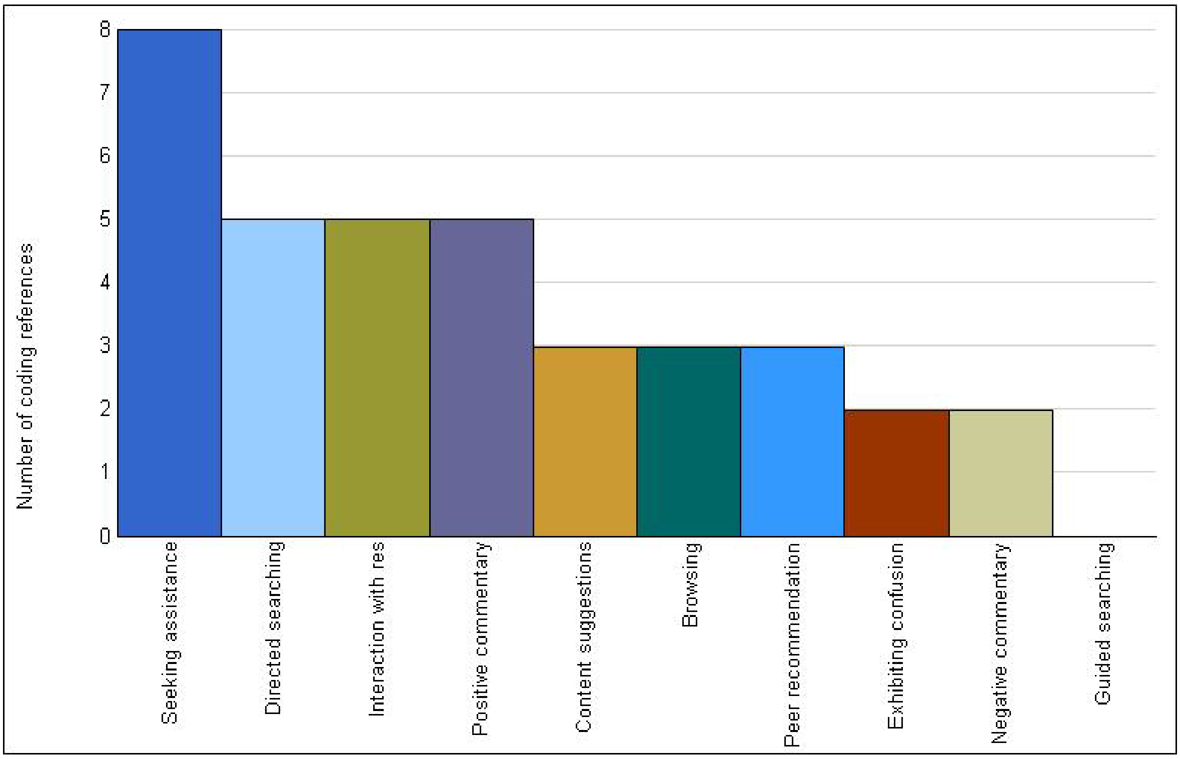


Figure 7.10 Number of instances coded to each node

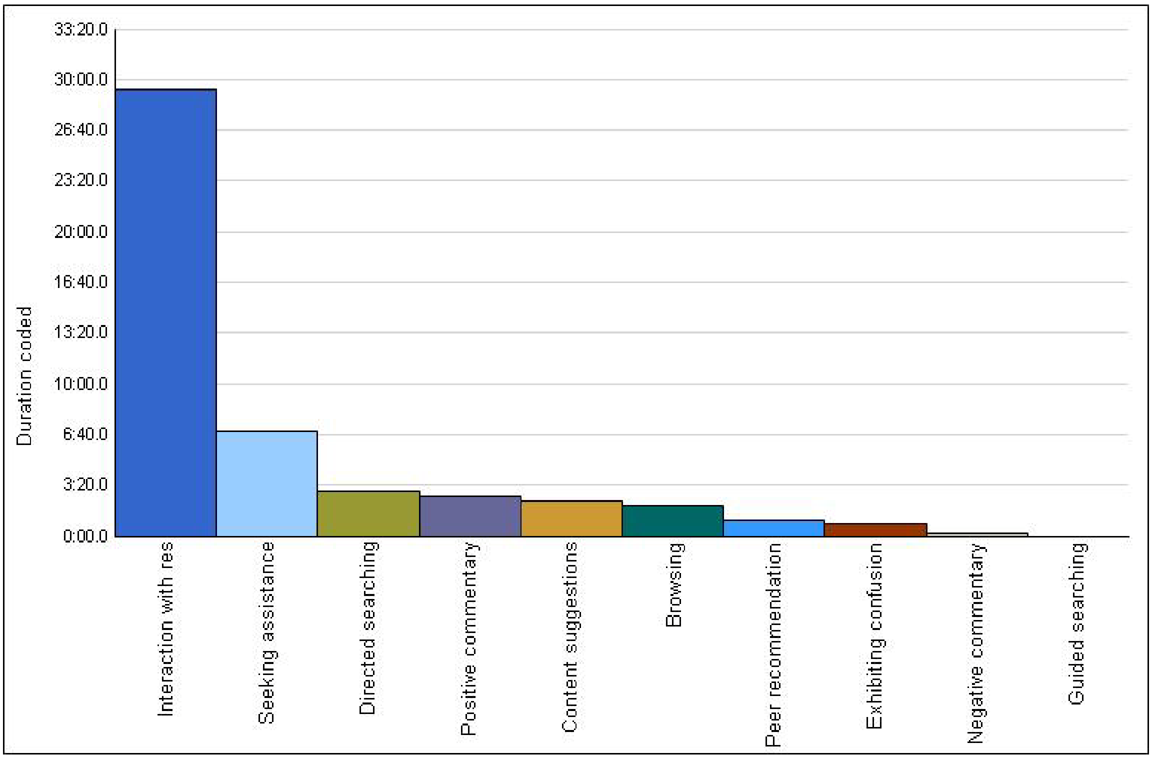


Figure 7.11 Duration of all instances coded to each node

Overall, group 4 viewed the site and various resources quite positively. Some content was suggested by participants for addition to the site, particularly video tutorials containing worked solutions, a preferred mode of learning identified by the group in the

preliminary interview. Despite the positive reaction to the resources and seemingly productive engagement with them, none of the students in group 4 revisited the learnmechanics.org database.

Table 7.5 resources accessed via the learnmechanics.org site

Resource	*User*	*Date*	*Time*
eCourses: Dynamics	a & d	5/10/2010	11:39:33 AM
eCourses: Dynamics	b	5/10/2010	11:39:36 AM
Videos: Momentum and impulse, circular motion	b	5/10/2010	11:39:58 AM
Purple Math	a & d	5/10/2010	11:40:39 AM
eCourses: Dynamics	b	5/10/2010	11:42:03 AM
eCourses: Dynamics	a & d	5/10/2010	11:42:21 AM
Engineering Dynamics Self Assessment	b	5/10/2010	11:43:18 AM
eCourses: Dynamics	a & d	5/10/2010	11:44:19 AM
eCourses: Dynamics	b	5/10/2010	11:44:20 AM
Videos: Momentum and impulse, circular motion	c	5/10/2010	11:45:32 AM
eCourses: Dynamics	c	5/10/2010	11:46:59 AM
eCourses: Dynamics	b	5/10/2010	11:55:27 AM
Cross Product Tutorials	c	5/10/2010	11:55:29 AM
eCourses: Dynamics	b	5/10/2010	11:55:52 AM
Dot Product Tutorials	a & d	5/10/2010	11:56:28 AM
eCourses: Statics	c	5/10/2010	11:56:57 AM
eCourses: Dynamics	a & d	5/10/2010	11:57:27 AM
eCourses: Dynamics	a & d	5/10/2010	12:12:56 PM

7.3.5 Results overall

This small group of participants demonstrated some quite different approaches to engaging with alternative learning resources. Student 1 exhibited a somewhat ineffective approach to identifying and selecting resources. Student 1 did not initially target resources relating to problems identified with dynamics during the session, but

did revisit the database independently after the session to explore other resources. In contrast to his unstructured browsing of learning resources, student 1 was keen to engage the tutoring offered by the facilitator at the conclusion of the observation session. This indicated a preference for a more teacher-led approach to learning-focused activities, a preference also apparent among student focus group participants seen in Chapter 6.

Students 2 and 3 were both mature age and appeared to be motivated and self directed learners in comparison to other participants. These two students were critical of the site and resources and did not revisit the database after the session. It was apparent that Students 2 and 3 had already developed their own self-directed learning strategies and did not see the online resources highlighted in this research as useful.

The four participants working in a study group setting had identified a range of abilities in Mechanics and engaged with the database and learning resources in a completely different manner. This group collectively identified a learning need (the current week's tutorial topic) and used the database with assistance from each other to identify a relevant resource. This approach differed from other participants in that the resources were utilised in conjunction with a collaborative learning approach. This utilisation also differed from the approach that many resource developers intend. The majority of the resources listed in the database were developed to aid students working in solitude (Burrows, 2009; Philpot, et al., 2005; Prusty, et al., 2009; P. Steif & Dollár, 2009). The approach taken by this group was also quite different to the individual focused teaching and assessment strategies that are dominant in the four Mechanics courses explored in this thesis (see chapter three).

There were other similarities between the outcomes of the preliminary interviews and the research discussed in previous chapters. All the participants in this research discussed teaching approaches by comparing the practices of different tutors and lecturers. Students also tended to indicate their learning preferences in terms of what had been presented to them previously, particularly the format of PASS classes. Both of these themes were also apparent in the student focus groups, and highlighted the fact that students tended to refer to what is known when referring to the teaching context. Student's 1, 2, and 3 also indicated that they had some trouble understanding certain concepts (conceptual knowledge), but that solving problems using these concepts

(procedural knowledge) was often the biggest challenge. This reflects a clear outcome of the examination transcript analysis in Chapter 4 in that the focus of students efforts in the process of learning may be externally driven towards surface approaches.

7.4 Chapter Summary

Key limitations for these results were the small participant group and the lack of multiple researcher analysis of the video observations. However, the results presented here were not intended to describe the prevalence of any particular learning preference or the quantified popularity of any particular resources. This component of the research was intended to identify what approaches to utilising alternative learning resources may exist. In this sense, the small group, exploratory, qualitative approach used here delivered useful results, particularly in light of outcomes of the research described in the preceding chapters.

In terms of the process stage of Biggs 3P model, three very different approaches to learning-focused activities were observed in this small participant group. According to Biggs' model, these differences were most likely the result of how student factors like motivation, ability, and prior knowledge interplayed with the learning resources available. However, the model does not give great insight into how to effectively accommodate these differences.

The other issue that was considered was how the teaching context (online learning resources) impacted on the process of learning. The possible issue of online resources encouraging repetition of typical problems, rather than deepening students engagement with the content was highlighted in Chapter 2. This study presented in this chapter was too small to explore this in great detail. However, the nature of students' engagement with a range of online resources that was observed here indicated that participants were not willing to independently engage with the resources to the extent some resource developers may have intended. It appeared as though the online courseware needed to be formally linked to assessment (product) to encourage deeper engagement with the resource (Paul Steif & Naples, 2003).

There is evidence from this observational study to suggest that students' who find Mechanics a challenge will interact with other people for assistance. Despite many

different options for learning support that students have, engagement with other people appears to be the preferred alternative during learning-focused activities.

Chapter 8

A Holistic Model for Engineering Mechanics Education

8.1 Introduction

The research presented up to this point considered several dimensions of teaching and learning in Mechanics, including the learning context, students' academic background, assessment, the views of students and staff in first year engineering Mechanics subjects. This approach provided a range of different perspectives on the teaching and learning in first year Mechanics. In each chapter the findings from the research were drawn together with the aid of Biggs 3P model of learning and teaching (J. Biggs, 1999). To examine the potential of the 3P model as a holistic model for designing Mechanics courses, findings from the preceding chapters in relation to this model are brought together in this chapter. This chapter summarises the mapping of research findings to the 3P model and proposes changes to create a new model for rethinking the way Mechanics courses are structured and delivered.

8.2 Mapping research outcomes to the 3P model

Figure 8.1 is a visual representation of how the research outcomes described in the five preceding chapters fit within the 1999 version of Biggs 3P model of learning and teaching. This figure maps out how each component of the research contributed to the development of a holistic view of engineering Mechanics education. The outcomes from some chapters can map to more than one dimension of the 3P model, so the findings from all of the components in the research in relation to each Biggs 3P model are summarised below in terms of Presage, Process, and Product, and are not in chapter order.

8.2.1 Research Outcomes Relating to Presage

Factors relating to the *presage* stage were explored in all five preceding chapters and are split into *student factors* and *teaching context* below, in accordance with the 3P model.

Student factors

The analysis of students' academic background in Chapter 5 and the student focus group outcomes in Chapter 6 gave significant insights into the presage stage and its relationship to other stages of the 3P model. The analysis of students' academic

achievement prior to Mechanics indicated there is a link between their previous achievements and learning outcomes. However, the nature of this link, whether it was related to prior knowledge or simply academic study skills, was not clear. As the statistics showed, the relationship between largely unrelated high school subjects was just as strong as that of closely related content. In addition, the strongest relationships identified were between Mechanics grades and grades in subjects students took concurrently (see 5.2.4). The academic background analysis did not explore any reverse link between learning outcomes and student factors, and provided no insight in the relationship between prior knowledge and achievement and the process stage of the 3P model.

The qualitative analysis of student focus groups did provide some further insight into these other relationships, and comments by student participants on the impact of academic history indicated there was a perceived relationship between prior knowledge in physics and mathematics and success in Mechanics, as suggested by Biggs (see 6.4.4). Indeed, comments by students indicated that this link was more related to their engagement with learning activities, such as their ability to complete tutorial problems and understand lectures, so between these comments and analysis of their academic background the outcomes from this research appear to align with Biggs' model.

In terms of motivation, however, the evidence from Chapter 6 suggests an alternative scenario to that proposed by Biggs. In Biggs 3P model, student motivation was placed within the presage stage as an attribute before learning occurs. This positioning was also supported by views expressed by some academics' during the interviews analysed in Chapter 6. The evidence from the student focus groups conducted in this research seemed to indicate that the reverse was also true. While the lightweight arrows in Figure 8.1 do suggest there is a reverse relationship, the students reported learning-focused activities, the teaching context, and learning outcomes as key factors impacting on their motivation to study and learn (see 6.5.2). Outcomes from this qualitative study, as well as other literature suggest that assessment, in terms of both the learning activities contributing towards assessments and the assessment outcomes, are key drivers for student motivation (see 6.5.2) (Alpay, et al., 2010; Boud, 2010; Ramsden, 1992).

Teaching context

The research described in Chapters 3, 4, and 6 dealt with aspects of the teaching context. Chapter three explored the content and format of four Mechanics courses which formed case studies for this research. This exploration of the teaching context identified a varied range of targeted learning objectives, and while some similarities in course learning outcomes were apparent, it became clear that 'introductory engineering Mechanics' is not a universal set of topics. A comparison of the major assessment components in all of these courses that are used to measure the final *product* of the learning process also highlighted some interesting points that related to outcomes described in other chapters.

In this comparison exercise, academics responsible for planning and running these courses were asked to compare the difficulty levels of typical examination questions used in each institution. Numerous differences emerged in educators' perception of content difficulty. Comments from the academics involved in the comparison exercise suggested that learning outcomes observed in previous years had fed back to the planning of assessments by informing their expectations of students' abilities, though not in a formalised manner. In terms of the 3P model, this indicated that there was indeed a level of feedback from product to presage (see 3.4 and Fig 8.1).

The relationship between assessment (presage) and product became clearer in the detailed final examination analysis described in Chapter 4. The analysis of the final Mechanics examination papers against Romiszowski's knowledge schema (Romiszowski, 1981) suggested an emphasis on procedural knowledge over conceptual knowledge (see 4.5.1). This was reflected in the learning 'product' where a majority of students' errors were categorised under procedural knowledge. It was also evident from students' approaches to study highlighted in Chapter 6 that typical Mechanics problems set in the teaching context, were leading to a surface approach to learning focused activities (tutorial questions, quiz study etc.) by students. This relationship between the teaching context, students approaches to learning, and the learning product is consistent with Biggs' 3P model (the bold arrows), and underlined the importance of the teaching context that is set before learning occurs. The emphasis on assessing procedural knowledge, and the process of learning procedural knowledge proposed by Romiszowski, was also reflected in students' self reported motivation for study (see

6.5.4). This confirmed the interrelationship between *teaching context* and *student factors* shown in the model.

Interviews with Mechanics educators also detailed common approaches to teaching in Mechanics and the apparent ethos behind these approaches. Students tended to expect a level of direction and leadership from teaching staff in the classroom. However, these expectations were not likely to be met according to the views and teaching methods raised by the academic staff interviewed (see 6.5.1). This indicated a disconnect in the interrelationship between *teaching context* and *student factors*, as shown in Figure 8.4. Students and staff both reported that this disconnect was causing problems for learning focused activities and subsequent learning outcomes. It became apparent that in the Mechanics courses explored here, the interrelationship between the two dimensions of *presage*, *student factors* and *teaching context*, was problematic.

8.2.2 Research Outcomes Relating to Process

The qualitative research in Chapters 6 and 7 provided a detailed account of how students engage with learning-focused activities in Mechanics, and how they are designed. As highlighted in 8.2.1 above, both students and staff reported superficial and ineffective approaches to study driven largely by assessments (see 6.5.2). This relationship between assessment (presage), students' approaches to learning (process), and the interrelationship of these with learning outcomes in Mechanics (product) is in alignment with the 3P model.

What was apparent from observations of students' interaction with alternative learning activities was the wide range of approaches utilised by only a small sample of students in the participant group (see 7.4). Biggs does highlight that "[presage] factors interact at the process level to determine the student's immediate learning-related activities, as approaches to study" (J. Biggs, 1999, pp. p. 18-19). This statement aligns with what was observed in Chapter 7 where differences in students self reported motivation, approaches to study, and academic ability corresponded to different ways of engaging with online learning resources. It was also apparent from the student focus groups, where a uniform teaching context (in terms of content, assessment and institutional practices) was met with a variety of approaches to learning by students. Thus, this research was able to confirm that the way in which students engage with learning activities is highly individual.

However, planning Mechanics education to account for these individual approaches to learning focused activities is a significant challenge. Students reported a preference for teaching styles that were more flexible and responsive to their learning needs in focus groups (see 6.4.1) and in preliminary interviews conducted before the observation sessions (see 7.3). Even when provided with a wide variety of online learning resources, students appeared to prefer interaction with others when difficulties were encountered (see 7.4).

8.2.3 Research Outcomes Relating to Product

The analysis of students' final examination transcripts described in Chapter 4, and the exploration of their academic backgrounds described in Chapter 5 provided insight into learning outcomes in the four first year Mechanics courses investigated here. An analysis of students' final examination transcripts suggested that the learning outcomes were quite dependent on the presage and process because the topics that they struggled most with differed between institutions (see 4.4). Differences were apparent in course content and the slight difference in course structure and assessment identified in 3.1 resulted in different learning outcomes. This indicates a good fit with Biggs' 3P model where learning outcomes are directly influenced by the inputs and processes within a Mechanics course.

From investigating the problems students encounter at the topic level within each institution, the analysis outcomes described in 4.3.2 showed many different learning outcomes, given the uniform learning activities and approaches to assessment that they encounter. Given that the teaching context was the same, as seen by all students in each course, the differences in outcomes within each course pointed towards the importance of student factors and their subsequent approaches to learning focused activities.

The investigation of student factors at the presage level in Chapter 5 suggested there were some strong correlations between their academic preparation and academic performance in Mechanics, as suggested by Biggs. However the nature of these correlations, whether they are related to prior knowledge or general academic ability was not clear from the statistical analysis conducted (see 5.3). As explained above in 8.2.1, students participating in the focus groups conducted in this research indicated a belief that their academic background did affect their approaches to study, but they did not link academic background directly to learning outcomes. Biggs also suggests

motivation as a factor in the student aspects of presage that subsequently affect learning outcomes. The qualitative study presented in Chapter 6 indicates that self reported motivational factors vary from student to student in nature and in their impact on study approaches. Hence, linking any one factor, or range of factors to observed learning outcomes has not been possible, the relationship appears to be more complex.

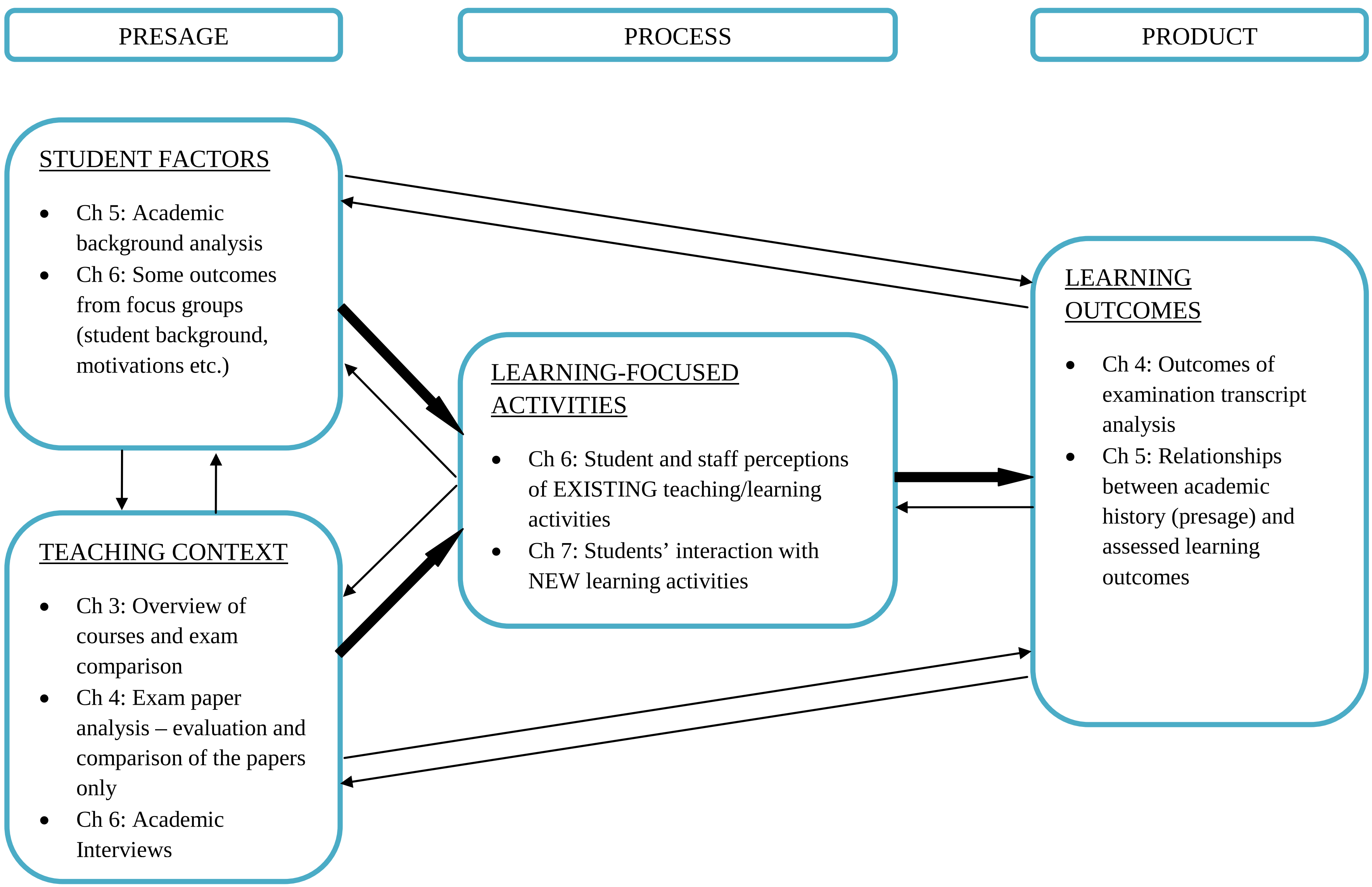


Figure 8.1 Research activities mapped to Biggs' 3P model of learning

8.3 Limitations of Biggs' 3P Model in an Engineering Mechanics Context

After mapping the key outcomes of this research to the 3P model, consideration was given to how this model may be applied to the planning and implementation of first year Mechanics courses. Overall, the mapping of outcomes from this research largely confirmed the 3P model of learning and teaching. The key alignment with the 3P model was related to assessment driven learning. It was observed that the format of first year Mechanics courses, and their predominantly summative approaches to assessment (presage – teaching context) were reflected in students' self reported approaches to learning (process). The results of this process were then observed in students' responses to final exam transcripts as predicted by the model (product). There were, however, a number of limitations to the 3P model observed here that could limit its effectiveness in improving first year engineering Mechanics education.

The foremost concern was the consideration by the model of motivation as a predominantly *presage* factor. Motivation was an issue several of the academics interviewed considered to be an attribute brought into the classroom and other learning activities by students, in agreement with the 3P model. In contrast the students participating in the focus groups talked about motivation in terms of the effect of teaching, assessment, and learning outcomes on their approaches to study. Students situated motivation as a factor that influenced and was influenced by all three stages of the 3P model.

Biggs' 3P model also suggested an interaction between student factors and teaching context at the *presage* stage. The research presented in this thesis indicated there was limited interaction between these two elements, particularly in regards to expectations of the teaching and learning process by students and academics (see 6.5.1). The interaction that Biggs' 1999 version recognised is a passive one because the model does not adequately highlight that this interaction should be a purposeful interaction that influences students' approaches to learning activities (*process*) if key issues around their motivation and approaches to study are to be addressed.

Students and academics who participated in this research also talked about interactions at the *process* level. Biggs' 3P model situates teaching within the *presage* when there was clearly interaction between teacher and student during learning focused activities. Students expressed a desire for more of this interaction in real-time response to their

learning needs (see 6.4.1). This was also clear in some student participants' engagement with online learning resources, with some students deferring to the facilitator or other student present in the room for assistance (see 7.4). Both the current teaching practices in the four Mechanics course and the online learning resources tended to fit with Biggs' model of teaching where content, structure, and assessment are set at the presage stage before learning occurs. There appears to be a need to re-situate teaching as an element of the learning process that is more responsive to learning needs.

These issues indicated that Biggs' 3P model may have oversimplified some of the more complex interactions between elements of the model that were observed in this research. This was particularly the case when the interactions between learner and teacher discussed in Chapters 6 and 7 were considered. There are some aspects of the teaching and learning process in Mechanics that can be controlled by the teacher and others that are controlled by the student. The many differences in student approaches to learning and teachers approaches to teaching, academic background, and finally, learning needs, also suggest that a level of responsiveness to these needs is required. The 3P model as it stands does not adequately allow for a high level of responsiveness, nor does it clearly indicate where purposeful interaction between teacher and student should occur.

So is Biggs' 3P model is an appropriate tool for designing Mechanics courses to address many of the issues highlighted in this research? While many of the research outcomes were explained well by the model, the limitations identified above led the Author to conclude that revisions were needed.

8.4 A revised learning model: The Student-responsive 3P model

Revisions and adaptations of the 3P model are not new. Section 2.4 highlighted how the model has evolved over time and been considered in different ways. The model revision proposed here takes into account the limitations of the Biggs' 3P model that were highlighted in 8.3. The revised model is referred to below as the 3P student responsive model, abbreviated to 3P-sr. The 3P-sr model was developed from a course design frame of reference and it should be seen as a tool for designing Mechanics courses more than as a representation of how students learn. It is also intended to be seen by students in Mechanics to help them understand their position and role within the teaching and learning of Mechanics. Used in this way, the 3P-sr model is intended to help students

and educators to see Mechanics education as a system and move away from the disconnected issues identified in 6.5.3.

The 3P student responsive model shown in Figure 8.2 maintains the useful distinctions between Presage, Process, and Product. However, it more clearly distinguishes and clarifies the factors in the teaching and learning process that can be best controlled by the student and those that can best be controlled by the teacher. The arrows in the model indicate the direction of influence between different elements in the model which <u>should</u> occur, in accordance with the research outcomes presented in this thesis. The purpose of this is to clarify how teacher and student should interact to address the issues identified in first year Mechanics education. As such, the minor interactions suggested in Biggs' 3P model by light arrows have been removed for greater clarity. The new model is explained below in terms of the interactions between elements of the model. Changes from the original 3P model refer to alterations that have been made to the version of Biggs' 3P model published in 1999 (J. Biggs, 1999).

Teaching context – Student factors

Biggs describes these elements of *presage* as attributes of education that exist "before learning takes place" (J. Biggs, 1999, p. 18). The 3P-sr model maintains this description, but emphasises that there should be a purposeful interaction between them. This is intended to address the issue of the mismatched expectations in the learning experience and teacher support that were identified in 6.4.1 and 6.4.5. Students expressed frustration with academics' expectations about how much they know and understand before class, while academics expressed frustration about how much work students would do in preparation for class. For Mechanics education to move forward, more interaction is necessary at this stage to clarify expectations and allow students and educators the opportunity to better understand who they are working with in the learning *process*, and importantly, how they will work with them.

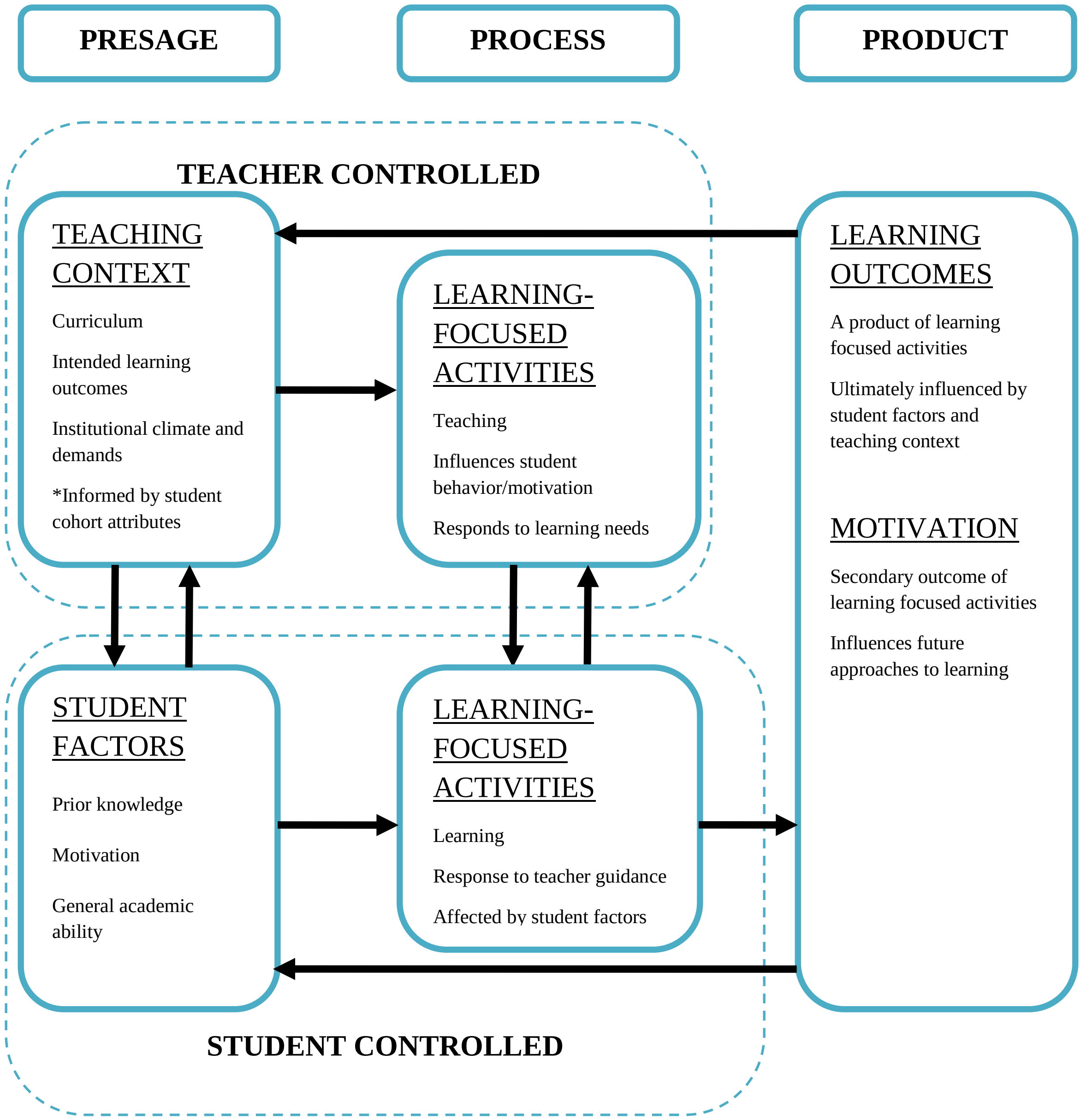


Figure 8.2 The 3P student responsive (3P-sr) model of learning and teaching for Mechanics

Teaching context – Learning focused activities

The 3P-sr model moves 'teaching' to the *process* stage of the model and replaces it with 'curriculum'. This was done to highlight the importance of teaching in the learning process, and that it is not something that should exist or be determined "before learning occurs". Curriculum encompasses content, assessment methods and structure, and resourcing and other factors that must be determined before teaching can commence. Curriculum informs teaching, as do intended learning outcomes, and the institutional

climate. The intent of this change was to emphasise the fact that teaching needs to be responsive to the learning needs of students during the learning process.

Student Factors – Learning focused activities

The attributes of students that *student factors* encompass has been retained from the original 3P model. Students and staff both indicated that their prior knowledge of the subject matter related to the way Mechanics impacted on their ability to engage with learning-focused activities (see 6.4.4). There was also some indication that students' personal motivations prior to engaging with learning activities had an effect on how they responded to particular types of learning activities. This was shown in students varied views on continuous assessment, lecture styles, and class attendance, etc (see 6.4.1). Students' general academic ability, as explored in the analysis of academic backgrounds in Chapter 5, appeared to link to learning outcomes measured as achievement. However, as the nature of this link was unclear, the 3P-sr model proposed that this link is affected by how students use their academic ability during learning-focused activities.

Learning focused activities (teacher controlled) – Learning focused activities (student controlled)

The original 3P model's treatment of *process* was somewhat limited in the author's opinion because process focused on how students engaged with learning and neglected the teachers' direct role in *process*. Students' comments on educators and educators' comments on students presented in Chapters 6 and 7 clearly indicated that there was, or at least should be, interaction between student and teacher within the learning process. The relationship between the teacher controlled aspects of learning focused activities and the student controlled ones shown in the 3P-sr model emphasised this two way interaction. It clarifies that as students engage with learning activities, they will respond to teacher guidance, just as the guidance provided by teachers should be responsive to student's learning needs.

This treatment of the process in the 3P-sr model does present some complications when considering independent study and web based learning resources. In these cases, learning resources themselves can be considered as the teacher controlled aspect of learning focused activities. The importance of this was observed in how students

engaged with online resources (see Chapter 7). Where resources did not provide a suitable response to their learning needs, the student response was to try a different resource. Students' comments regarding independent study in 6.4.1 also highlighted the need for suitable interaction between student and resource. Some student participants outlined their frustration at spending hours studying and not having enough information within the prescribed text (in most cases, worked examples) to overcome roadblocks encountered while trying to solve Mechanics problems. In this instance, it could be considered that the textbook, as teacher, was unable to provide the guidance needed by the student. So in the design of learning focused activities, whether face-to-face or via learning resources, the 3P-sr model highlights how response to learning needs and the students response to the guidance provided must be given adequate consideration.

Learning focused activities (student controlled) – Learning outcomes

The 3P-sr model presents product ultimately as the outcome of the student controlled dimension of learning focused activities. This has been done to emphasise that the teacher can support, inspire, guide, and encourage students to learn, but that responsibility for learning ultimately rests with the student. Since the model is also intended as a map for students, this positioning seeks to address some students' expectations of learning as a passive process led by the teacher that were discussed in 6.5.1.

Student motivation in the learning process has been discussed extensively in the engineering education literature (see 2.2.1) and was raised by both academics and students in Chapter 6. To address this, *Motivation* has also been added as a *product* of the learning *process*. This emphasises the significance of learning focused activities in improving or negatively impacting on students' motivation for continued learning.

Learning outcomes – Presage

The original 3P model suggests a direct two-way relationship between *presage* and *product.* The reverse link between learning outcomes and teaching context was identified in 3.3, where engineering academics commented that the learning outcomes observed in previous years informed the design of course content and structure. Outcomes of the focus groups reported in Chapter 6 also suggested a reverse relationship between product and presage, mostly in term of student motivation (see

6.4.2). The forward relationship between teaching context and learning outcomes was observed in the exam analysis in Chapter 4, where differences between Mechanics courses resulted in different learning outcomes. The forward relationship between student factors and learning outcomes was also identified in terms of academic ability (see Chapter 5).

However, in the case of the forward relationships between the presage and product observed in this research, exactly how these relationships worked was not clear. While there was a correlation between *presage* factors and *product*, correlation does not equate to causation. The Author believes that these forward relationships cannot operate without influence from *process*. The reverse relationships between product and process were identified from concrete statements from students and academics, statements that suggested a causative link between product and presage. From the academic perspective, observed learning outcomes among students directly informed how they assessed future cohorts. From the student perspective, marks achieved in assessments affected their motivation for future assessments and early concepts they did not understand affected the prior knowledge needed for follow on topics (see 6.4.4). For these reasons the 3P-sr model eliminated the direct forward relationship between *presage* and *product*. The result is that the 3P-sr model becomes cyclical rather than linear.

8.5 Implementing the 3P-sr model in an engineering Mechanics context

The 3P-sr model is presented here as the main outcome of this research. The model emphasises the need to consider the design of Mechanics education in a holistic sense, taking into account contextual factors, student backgrounds, learning objectives and so on at each stage of the teaching and learning process. This presents difficulties in terms of proposing a detailed plan for a first year Mechanics course in this thesis as any proposed plan would hypothetical and may not be useful in practice. The 3P-sr model presents a guide for designing courses that are bespoke, and likely to differ between institutions. In fact, a core attribute of a 3P-sr designed course is that it is likely to, and even needs to be unique, having been carefully designed to accommodate institution specific teaching skills and learning needs, and the interrelationships between various influences on teaching and learning.

In many cases, including the four courses explored in this research, use of the 3P-sr model may require a complete redesign of the course. The views strongly held by academics interviewed in chapter 6 suggest that such a redesign would require the staff responsible to start with a blank canvas to avoid retaining ineffective practices and course materials. Involving students in the course design would also assist in properly accounting for various student-controlled factors.

While presenting a detailed, whole course design was not possible here, examples of possible revisions to existing teaching practices described throughout this thesis are presented below to clarify the intentions and usefulness. Examining existing practices was also a useful way of highlighting the differences that may result from utilising this model. The examples are explained using the 3P-sr as a roadmap, and it may be helpful for the reader to refer to the model while working through each example (see figure 8.2). While teaching methods described in the examples below may not necessarily appear groundbreaking, they demonstrate the usefulness of the 3P-sr model as a Mechanics curriculum development tool than can be used to identify where new teaching approaches may be needed and which ones might be appropriate. An entire Mechanics course redesigned using the 3P-sr model may incorporate elements of the cases described below.

8.5.1 Example 1: lectures designed around the 3P-sr model

The lectures described by student and staff participants in chapter 6 suggested a largely one-way transmission model of teaching. While this approach may be necessitated by the size of the class and in many cases, the layout of the lecture theatre, it does not adequately accommodate the many different learning styles and pace, and prior knowledge apparent in the student cohort. The format also reinforces the role of the student as a passive learner. While the large lecture format is less than ideal according to the 3P-sr model, improvements could be made. A lecture process developed around the 3P-sr model should contain strategies for addressing presage and process factors, and utilise the product factors as the key motivators for students.

Presage and product

It is important to acknowledge that like any other format, lecture based learning-focused activities are situated between pre-existing factors (presage), and the intended outcomes

of the activity (product). The lecture is a process, not a beginning or an end point. The situation of the lecture within the broader curriculum should inform the selection of focus topics for the lecture, and importantly, the identification of ‘critical ideas’ that will be built upon in subsequent learning activities. The structure of the lecture should be driven by the learning goals for that class, recognising that learning goals may extend beyond content to include skills for independent learning etc. Structure and content should also take into account understandings of student factors such as prior knowledge and motivation from previous assessment outcomes and classes.

Process

From the beginning of the lecture, the roles of student and teacher should be clearly understood by the educator, and communicated to the students. The teacher should be positioned as the guide, rather than a centre of knowledge, while the student should take on the lead role in the learning. A clear understanding of these roles is critical to maintaining consistency and coherence throughout the class to avoid messy and confusing transitions between teacher lead and student lead learning activities. This consistency is made more important as students are likely to be familiar with teacher-focused lectures and may resist a shift towards student-led activities.

When introducing new concepts or working through examples, the 3P-sr model highlights the importance of responding to varying student learning needs and differences in prior knowledge. This can be addressed in the large class setting to an extent by referring back to ideas upon which new concepts or examples are built, and highlighting the prior knowledge required to properly understand the new concept. However, even employing active lecturing techniques such as quick quizzes, think-pair-share activities and so on, it is still not possible to accommodate all learning needs as derived from student factors. Such are the limitations of the large class lecture format. Newly introduced ideas in the lecture setting need to be clearly linked to alternative options for learning, along with an acknowledgement to students that the concept may be complex or challenging. With this in mind, the lecture is more usefully positioned as the backbone of the curriculum, to which all other learning activities, in-class or independent, are connected. Viewed in this way, the lecture becomes a tool to guide the learning process, rather than a content delivery tool. The lecture format would become

more about understanding how to learn Mechanics, supported with appropriate technical content to focus each class.

8.5.2 Example 2: Tutorial classes designed with the 3P-sr model

The typical tutorial class format used in the four Mechanics courses at the centre of this study focussed on solving typical textbook problems from US sourced texts such as Hibbler (Hibbeler, 2007, 2010) and Meriam and Kraige (J. L. Meriam & Kraige, 2008a, 2008b). As reported by academic and student participants in Chapter 6 and in the subject outlines in Appendix A, tutorial classes involved the tutor either leading the class in solving these textbook problems, or requiring students to solve the problems and ask questions where necessary. This approach incorporated occasional one-to-one support for students, but relied largely on the tutor presenting solutions or guidance to the whole class. This teaching method limits the tutor's ability to account for student factors and the space required for purposeful interaction between teacher controlled and student controlled aspects of learning-focused activities.

Redeveloping this approach around the 3P-sr model would require ways to accommodate greater, purposeful interaction between teacher and learner. It would also necessitate accommodations for various learning needs and academic preparation among students. With lectures repositioned as guides to the process of learning Mechanics (see 8.5.2), the importance of tutorials in supporting learning directly is emphasised.

Presage and Product

Like lectures, the content and structure of tutorial classes must be carefully positioned within the bounds of presage and product factors. The critical learning goals of the tutorial class should contribute towards the desired learning outcomes, with assessments utilised to motivate and focus students on learning-focused activities conducted in tutorials. The smaller class size of typical tutorials described in this research (20-30 students) allows for a more flexible interaction between student and educator than in the lecture context. Learning goals and the position of the tutorial class within the curriculum should be clearly understood by the tutor to ensure that interactions between are purposeful.

Process

As in the 3P-sr developed lecture format, the roles of the student and tutor in the tutorial class must be clarified and maintained with consistency. Tutors should be positioned as learning guides and motivators, while students lead the learning. By removing the tutor from the leadership role, the tutor is then free to identify individual learning needs by working closely with individual students or small student groups. The tutor can then provide appropriate support by addressing gaps in prior knowledge, re-articulating ideas or concepts that have been misunderstood, or providing encouragement to motivate individuals.

Encouraging students to lead the learning process will accommodate the collaborative learning approaches that students demonstrated in chapter 7, and which student participants described in terms of study groups and PASS classes in chapter 7. Emphasising the need for students to work through Mechanics problems at a suitable pace, and with support provided by the tutor will ensure that tutor and student roles in the learning process are clear and interactions are purposeful. Clarifying roles in this way will also help to address mismatched expectations that were apparent between students and educators.

8.5.3 Example 3: in-session assessments designed with the 3P-sr model

Assessment in the four Mechanics courses studied in this research was dominated by procedural knowledge focused quizzes and examinations. The effect of this was to encourage students to take on surface approaches to learning, practicing standard problems and studying worked examples without engaging with the content deeply. The 3P-sr model highlights the importance of assessment of learning in motivating students. By considering assessment as a mechanism within the teaching and learning system, learning outcomes and assessment can be harnessed to influence students' approaches to learning-focused activities.

The lecture and tutorial cases described above emphasised revisions to the *process* which were informed by the *presage* and *product*. Assessment can also be considered as a *process* that is developed as part of the teaching context (presage) and guides students towards the desired *product*. Current Mechanics assessments focused largely on summative methods where *purposeful interaction* between student and teacher occurred

after the product of learning was apparent. 'Purposeful interaction' is emphasised as independent study for quizzes and examinations, with texts, lectures or peers as 'teacher', is not undertaken with clear goals in mind during the interaction. The purposeful interaction only occurs on occasions where results are reviewed and feedback is responded to.

In session assessments designed around the 3P-sr model would support purposeful interaction between teacher and student prior to the assessment. Such assessments could include a series of design tasks or analytical assignments that require students to interact with teachers in the course of working towards a particular outcome. If situated appropriately within the curriculum, this approach could ensure that assessment provides appropriate motivation for students to engage with these learning-focused activities. Such assessment practices are not novel, but as chapter 3 showed, they are not commonplace in Mechanics.

In designing these assessments, it is also critical to consider how measured learning outcomes and feedback will feed back into the teaching context and student factors. Where misconceptions or poor understanding of analytical procedures are apparent, there needs to be opportunities for rectifying these issues to ensure that students' prior knowledge for subsequent learning-focused activities is adequate.

8.5 Chapter Summary

This chapter summarised the research findings from preceding chapters in terms of an existing holistic model of teaching and learning. By utilising Biggs' 3P model it was found that many findings of this research were explained quite well by the 3P model, although it did have some limitations in its ability to explain some of the research findings which would subsequently impact on its effectiveness as a tool to redevelop curricula in Mechanics courses. As a result, a new 3P student responsive (3P-sr) model was proposed that accounts for interactions between many factors in the teaching and learning process observed in the context of this research. The 3P-sr model was not tested in this thesis, but it is proposed as a useful guide for further work to address the problem of high fail rates in engineering Mechanics.

Chapter 9
Conclusion and Further Research

9.1 Conclusion

The purpose of this study was to create a more complete understanding of first year engineering Mechanics education to address the question:

What are the factors contributing to high fail rates in first year engineering Mechanics?

The research examined learning and teaching in Mechanics through a series of different perspectives, each using multiple research methods applied to different focus areas and mapped back to Biggs' 3P model of teaching and learing. This research has highlighted many different issues in the teaching and learning of Mechanics. These issues combined suggested a lack of effective holistic approaches to designing introductory engineering Mechanics courses.

Previous studies of student learning in Mechanics indicated that high fail rates are the norm and suggested that examples of holistic design of mechanics curricula are rare. A review of the literature relating to engineering Mechanics education identified many studies into the various factors that may be contributing to high fail rates and many different approaches that educators have taken to try to improve learning.

Of the many issues identified in the literature, most were studied in isolation to other influencing factors. The studies which focussed specifically on Mechanics tended to focus on specific issues in Mechanics, whether they were misconceptions (Espinoza, 2004; Hestenes, et al., 1992; Paul Steif, 2004; P.S. Steif & Dantzler, 2005; P. S. Steif, Dollár, & Dantzler, 2005; Streveler, Litzinger, Miller, & Steif, 2008; , student motivation (Alpay, et al., 2007; Balascio, et al., 2007; Crawford and Jones, 2007; Pollock, 2005) , teaching methods and interventions (Ji and Bell, 2008; Kessissoglou and Prusty, 2009; Linsey, et al., 2007; Philpot, et al., 2007) etc., and only reported on the outcomes of interventions addressed in these specific areas.

To understand how Mechanics education functions in a holistic sense, a holistic model of teaching and learning was identified from the higher education literature and used to structure this research. Biggs' 3P model, published in 1999, was identified as a suitable

framework for linking research findings into a holistic picture of teaching and learning in engineering Mechanics. This model had not previously been used in the context of engineering Mechanics education.

Benchmarking of content, pedagogy, and assessment in four first year Australian engineering Mechanics courses found that ‘typical’ first year engineering Mechanics courses are not structured around a universal set of topics, concepts, and analytical methods to be learnt by all students. This first line of investigation showed that while many similarities existed in the content of the four courses, there were significant differences. The research also discovered differences in engineering academics’ perceptions of the difficulty of questions in final examination papers. This indicated that an assessment of learning outcomes can be measured differently from course to course. While pedagogy was broadly similar at each of the four courses, there were differences in the way individual classes were run, assessments developed and marked, and how students were assisted outside of class. This again indicated that any definition of a ‘typical’ engineering Mechanics course would be problematic. However, despite these differences the fail rates for each course were similar, and high.

This research also indicated that common assessment practices may not be supporting effective approaches to learning. In the second line of investigation, a structured analysis of final examination transcripts suggested that while assessment of conceptual understanding did feature prominently, there was in fact a strong focus on a procedural knowledge of Mechanics. This indicated that existing teaching practices were potentially driving students to adopt surface approaches to learning, memorising facts and procedures rather than pursuing deep conceptual understanding. This type of assessment was not limited to the final examinations. In the four Mechanics courses up to 90% of the assessment may be an assessment of procedural knowledge over conceptual understanding.

In addition, it was apparent that there are no universally challenging topics or concepts in introductory Mechanics. Topics that caused most difficulty for students can differ between institutions, with challenging topics presenting at one institution and not at another. The exam paper and transcript analysis demonstrated that the topics that challenged students were wide and varied, indicating that problem topics in Mechanics appeared to be far from universal, which suggested that the challenging areas may be

more institutional or even class specific. There was also the possibility that these problem topics depend on the way in which assessments are developed and administered.

In considering incoming students background, this research demonstrated that often cited, cause-and-effect relationships between students' academic background and performance in mechanics did not always hold true. For the third line of investigation, a statistical analysis of the relationship between students' academic performance in High School and University subjects and their performance in first year Mechanics explored elements of the 'Student Factors' component of Biggs' 3P model. The analyses indicated that students' overall academic ability appeared to be more critical than prior knowledge. It also suggested that students with lower performing backgrounds were still capable of succeeding in Mechanics, and most did so. These findings did not highlight an explicit cause-and-effect relationship between academic background and success in first year engineering Mechanics.

Exploring the views of students and staff involved in a first year Mechanics course, it was clear that:

- Expectations of both parties are often mismatched.
- Students are focused predominantly on assessment outcomes.
- Both students and teaching staff focused on discrete issues in the teaching and learning process in the absence of an holistic overview.

This fourth, qualitative line of investigation explored all three stages of Biggs 3P model, presage, process and product, from the perspective of students studying first year Mechanics and academics teaching it. A number of strong underlying themes were identified. Firstly, there was a clear mismatch between student and staff expectations with frustrations expressed by all participants. Students expressed the need for more support through the learning-focused activities and a preference for the tutor or lecturer to take the lead. These expectations of teacher centred learning-focused activities were not matched by the opinions expressed by the academics. It was apparent that these mismatched expectations were creating barriers for efforts to improve teaching at the presage and process stage of the 3P model. This finding also indicated that

understanding and responding to some factors considered by Biggs to be part of the 'presage' to learning-focussed activities can only realistically happen as part of the 'process' of learning.

Secondly, driven approaches to learning engineering Mechanics were commonly reported. This theme reflected issues with assessment practices identified in the analysis of examination transcripts and benchmarking exercise. It appeared that the traditional quiz and written examination assessment methods that form the majority of assessment in Mechanics may have been encouraging surface approaches to learning. This highlighted both the relationship between assessment and student motivation identified in the 3P model and an apparent relationship between assessed learning outcomes and student motivation that was not clearly represented in the 3P model.

Thirdly, there was an overriding focus on one teaching and learning issue to the next with limited reflection on how each concern relates to the learning experience as a whole. This continued a theme evident in the engineering Mechanics education literature, where previous work to improve learning tended to focus on specific problems in isolation from the course as a whole. Participants also focussed on issues that were seen as beyond their control or responsibility, and there was little evidence that first year engineering Mechanics was being considered in a holistic manner.

In considering alternative approaches to teaching and learning of Mechanics, it was clear that approaches individual students take to learn mechanics are diverse and unlikely to be addressed with any single teaching intervention. This observation was identified through the fifth and final line of investigation which explored the 'process' stage of the 3P model through an observational study of students working with online learning resources. This research highlighted a diverse range of approaches to engaging with learning-focused activities and also supported findings from earlier focus groups that students desire a greater level of flexibility and responsiveness from the teaching context than are on offer with current online learning resources. This observational study also highlighted an apparent preference among participants for face-to-face interaction over online interaction.

These five lines of investigation have resulted in a comprehensive and holistic understanding of teaching and learning in first year engineering Mechanics education.

Many different factors contributing to persistent high fail rates in these courses have been identified and have been drawn together with the 3P model of teaching and learning. This study has demonstrated that when considering teaching and learning in a holistic sense, the 3P model supported many of the key findings. There were, however, a number of key problems which could not be adequately explained by the 3P model. These concerns have been incorporated into a revised 3P model which emphasises the cyclic nature of teaching and learning in Mechanics, and reflects the need for a more purposeful and flexible interaction between student and teacher. The revised 3P-student responsive model, abbreviated to 3P-sr, provides a framework for designing engineering Mechanics education that is based on evidence drawn directly from Mechanics education. It represents the first such model to be developed for engineering Mechanics education.

9.2 Further Research

The 3P-sr model was developed by adapting an existing teaching and learning model to incorporate the findings of this research, and as such, it represents a novel contribution to the field of engineering Mechanics education. While the 3P-sr builds upon a substantial evidence base, it is yet to be tested and validated in the development of a new engineering Mechanics course. The 3P-sr model was presented in Chapter 8 as a tool for designing whole courses, revising specific elements of a course such as assessments or tutorial classes, or as an educational tool to highlight student and teacher roles in the learning process. An implementation and evaluation of the model should consider its effectiveness when applied to Mechanics education in these different ways.

In addition to testing and validating the 3P-sr model, there were a number of other findings throughout this study that could be explored in more depth. Examining the relationship between academic preparation (presage) and performance in Mechanics (product) (see Chapter 5) revealed that many students who did not appear to have an appropriate background for studying Mechanics were still able to succeed, while others who appeared well prepared failed. A greater understanding of the relationship between learning outcomes and student factors outside academic ability could be developed by examining how these students progress through Mechanics courses.

This study identified a relationship between ‘product’ and reported student motivation by exploring the current students views on engineering Mechanics, views that were

collected at only one point in time. More could be understood about the relationship between assessment outcomes and student motivation by conducting a longitudinal study to capture their views at different points in time. A study that captured students' views before and after their first assessment task could further develop our understanding of the effect of assessment outcomes on motivation and approaches to study.

A modified version of Romiszowski's knowledge schema, the MRMF (see Chapter 4), was used to analyse the nature of typical assessments in first year Mechanics. This analysis identified an emphasis on procedural knowledge over conceptual understanding in engineering Mechanics assessment. The qualitative research presented in Chapter 6 subsequently indicated that this emphasis was reflected in how students approached learning in Mechanics. This framework could be utilised to analyse other assessment methods commonly used in engineering education to determine if this procedural knowledge focus, and subsequent student reactions to it is more widespread within engineering curricula.

These suggested areas for further research would expand the holistic understanding of engineering Mechanics education that has been framed by the 3P-sr model in this study. By utilising the 3P-sr model in designing and revising Mechanics courses and continuing to build on the research presented here, it is hoped that the effectiveness of Mechanics education and the quality of learning can be improved in years to come.

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Appendix A.1 ENGG152 Subject Outline

University of Wollongong

Faculty of Engineering
Subject Outline

Subject Code: ENGG152
Subject name: Engineering Mechanics
Pre/Co-requisites: Nil
Credit points: 6
Offered: Spring Session 2007, Wollongong Campus *26hrs lectures; 26 hrs tutorials; 6 hrs laboratory*

CONTACTS

Subject Coordinator
Zhengyi Jiang (Room 8.G25 Ph 42214545, Fax 42213101 jiang@uow.edu.au)
Subject Lecturer:
Prof T McCarthy (Room 4.G41 Ph 42214591 timmc@uow.edu.au)
Consultation times: Please see e-learning for times
Subject Lecturer:
Assoc/Prof Peter Wypych (Room 8.G19 Ph. 42213488, Fax 42213101 peter_wypych@uow.edu.au)
Dr O.C. Kennedy (Room 8.G25 Ph. 42213357, Fax 42213101 oliver@uow.edu.au)
Consultation times: Please see e-learning for times - *appointments may also be made using above contacts.*

Tutors: Dr O Kennedy (8.G25), Assoc. Prof P Wypych (8.G19), Assoc. Prof R T Wheway, Prof A K Tieu (8.G20), Dr Z Jiang (8.G25), Dr P B Kosasih (8.G24), Assoc Prof A Basu (8.G25), Anass Attya (4.111). **Statics:** Anass Attya (4.111), Prof T McCarthy (4.G41), Dr A Remennikov (4.137) Assoc.Prof Max Lowrey (4.G39), Dr N Sheikh (4.G43), Mr Pramod Thakur (4.111)

Laboratory: Assoc. Prof R T Wheway, Dr O.C. Kennedy (8.G26), Dr Z Jiang (8.G25), Dr P B Kosasih (8.G24), Anass Attya (4.111), Mr J Mulima, Mr C Lam

Students will be contacted throughout the Session via UoW SOLS Mail with important information relating to this subject.
N.B. UoW email and UoW SOLS mail are not the same. Messages sent to SOLS mail do not go to your email account and vice-versa.

Subject Outline: The subject comprises two interlinked but distinct parts: Part A Statics and Part B Dynamics. These parts will alternate every other week. See schedule for details.

Part A: On successful completion of this subject students will be able to:

1. Resolve components of forces and determine resultants of force systems.
2. Determine reactions, resultants and equilibrium conditions for rigid body systems.
3. Understand how internal forces are transmitted in beams and trusses and calculate shear forces, bending moments and axial forces in truss elements.
4. Determine the main cross sectional properties of shapes, namely, centroid, first and second moments of area and moment of inertia for solids. Students will gain an understanding of the applications of these concepts.

Part B: Dynamics of particles in rectilinear and plane motion; kinetics of particles; equations of motion; work and energy; impulse and momentum.

On successful completion of this subject students will be able to:

1. Understand **dynamics** ie. the motion of bodies without reference to the forces that cause motion.
2. Understand **kinetics** which deals with the relations of unbalanced forces and resulting changes in motion.
3. Comprehend the three basic principal methods of analysis: force-mass-acceleration, work-energy, and impulse-momentum.
4. Apply to simple practical problems found in contemporary engineering situations.

Lecture Times: Thursday, 14.30am - 16.30am, Room 40.Hope Theatre

Tutorial Times: Ten 2 hour tutorial timeslots have been arranged for this subject. Each student will attend **one** of these sessions, and will be able to enrol via SOLS. The tutorials will cover both the statics and dynamics components of ENGG152. Tutorial sessions will be available on Wednesday, Thursday and Friday.

NB: Retain the same tutorial rooms and groups for the Statics and Dynamics components of this subject.

LaboratoryTimes: Each student will attend 3 off 2 hour lab sessions (total of 6 hours) for statics and dynamics experiments in weeks 6 to 12. Students will be able to enrol **either** the Monday morning sessions (10.30 - 12.30 AM), Monday afternoon sessions (12.30 - 2.30 PM) or Tuesday morning, via SOLS, and will attend on alternate weeks. The labs are held in Thermo Lab in Building 6. Refer to Coordinator regarding Groups & Lab schedule.

Attendance in the Laboratory is COMPULSORY.

Method of delivery: Face to Face Lectures, Tutorials & Labs, some material also provided on WebCT

Study time: 12 hours per week per credit point. This includes lectures, tutorials, practicals and self study.

Assessment: The assessment total mark for the subject is distributed as follows:

Lab Reports (6) (approx. 2 page lab report, due 1 week after lab)	10%
Tut. Assignments (6) (Weeks 4, 5, 8, 9, 12 & 13)	30%
Final Examination (Held in End of Session Formal Examination Period)	60%

IMPORTANT INFORMATION ON THE TUTORIAL HAND IN ARRANGEMENTS

Statics tutorials take place in weeks 1, 3, 5, 7, 9, 11, 13. Dynamics tutorials take place in weeks 2, 4, 6, 8, 10, 12 There will be an in class Dynamics assessment problem in weeks 4, 8, 12 and a Statics assessment problem in weeks 5, 9, 13. Assessment will take place in the final 30 mins of the tutorial in the specified weeks and will be handed in at the tutorial.

- Students need to achieve a minimum of 40% in the final assessment (in addition to a composite mark of 50%, or better, overall) to be considered for a pass in the subject.
- Attendance at all scheduled classes is expected. however there are no minimum attendance requirements.
- The final grading of marks will be based on the raw total of marks obtained in the assessment tasks listed above.

Spring Session Final Examination (End of Session Formal Examination)

The Spring Session Final Examination (End of Session Formal Examination) will examine BOTH the DYNAMICS and STATICS components of this subject.

Textbooks:

Hibbler, R.C. Engineering Mechanics: Static, Edition, 11th Edition in SI units, Pearson - Prentice Hall (2007). Hibbler, R.C. Engineering Mechanics: Dynamics, 11th Edition in SI Units, Pearson - Prentice Hall (2007). A special value pack that includes both books plus their companion Study Guides can be purchased cheaper than buying the books separately. Students who already own copies of the previous edition (3rd SI Edition) can use that text.

Reference Books:

Beer, F.P. and Johnson, E.R (1998) Vector Mechanics for Engineers: Statics, McGraw-Hill, Third SI Edition. Library Catalogue number 531.32. Beer, F.P. and Johnson, E.R (1998) Vector Mechanics for Engineers: Dynamics, McGraw-Hill, Third SI Edition. Meriam, J.L. and Kraige, L.G. (1993) Engineering Mechanics: Vol 1 Statics and Vol 2 Dynamics, John Wiley and Sons, 3rd SI Ed. Library Catalogue number 620.104.1a

Hibbler, R.C. Engineering Mechanics: Static, SI Edition, 3rd Edition, Pearson - Prentice Hall (2004).

Hibbler, R.C. Engineering Mechanics: Dynamics, SI Edition, 3rd Edition, Pearson - Prentice Hall (2004).

e-learning:

An e-learning site has been established for this subject. It will contain basic information about this subject such as the subject descriptions for the Statics and Dynamics components; schedules for the tutorials and laboratories (in dynamics); lab notes and possibly some lecture material from the dynamics section of the subject. Details on how to access this e-learning site can be found from:

http://www.uow.edu.au/student/elearning/vista/index.html

Penalties

Late submissions of Laboratory Assignments will incur a penalty of 5% per working day off the maximum mark.

Submission of assignments and lab reports
All assignments and reports should be submitted with an assignment/report cover sheet. These cover sheets can be obtained from the Engineering Enquiry Centre (EEC, ground floor Bldg 4), and include a receipt section to be retained by the student as a record of the submission of the piece of work. Assignments and reports should normally be submitted to the relevant lecturer/tutor/lab instructor at the nominated time, but may be submitted at the EEC. Similarly, assessed work will normally be returned by the lecturer/tutor, but may be made available through the EEC (such an arrangement will be notified via the WebCT Vista subject site).

Safety
The over-riding responsibility of all students is to ensure that no action of theirs places the well-being of themselves or any other person at risk. When participating in laboratory activities, students must wear appropriate clothing and footwear (**footwear - thongs and sandals are not permitted; clothing - singlets and tank tops are not permitted**). Long hair must be tied back and covered appropriately to avoid injury from moving objects, etc. You must not use any item of equipment until you have permission from the officer in charge of the lab or the academic/tutor supervising. Consult the academic or officer in charge of the lab for further information about safe practices.

TUTORIALS SCHEDULE

Students will self-enrol over SOLS in one of the following tutorial timeslots. In week 1 there will be practice assessment done during the tutorial. From week 2 on the topics will alternate between Statics and Dynamics.

Tutorials

Group number	Day and time	Room number	Statics tutor	Dynamics tutor
1	Wed.: 10.30-12.30	19.G027	A Remennikov	A Basu
2	Wed.: 10.30-12.30	19.G024	Anass Attya	K Tieu
3	Thurs: 10.30-12.30	3.121	M Lowrey	P Wypych
4	Thurs: 10.30-12.30	19.G024	Anass Attya	Anass Attya
5	Thurs: 17.30-19.30	15.206	P Thakur	B Kosasih
6	Thurs:17.30-19.30	3.122	N Sheikh	R Wheway
7	Thurs:17.30-19.30	4.G31	T McCarthy	C Lam
8	Fri: 12.30-14.30	19.G024	P Thakur (if it runs)	TBA (May not run)
9	Fri: 12.30-14.30	67.203	T McCarthy	A Basu
10	Fri: 12.30-14.30	19.G027	M Lowrey	Z Jiang
11	Thurs: 10.30-12.30	1.105	N Sheikh	O Kennedy

ENGG152 DYNAMICS and STATICS LABORATORY EXPERIMENTS

Students will complete 6 laboratory experiments in the second half of the session (during weeks 6 to 13) dealing with dynamics principles studied during the course. A detailed schedule will be prepared later in the session, however the general arrangement is that each student attend the labs for three 2 hour sessions. In each session 2 experiments will be completed. The public holiday in Week 10 on Monday 1st October means that there will be no labs that week.

Experiment Details (held in Building 6, Thermo Lab)

1. Principle of Impact Momentum - Billiard Ball Motion
2. Polygon of forces
3. Energy Balance Experiment
4. Centrifugal Motion Rig
5. Determination of Coefficient of Friction Rig
6. Porter Governor Rig

University and Faculty Policies
Students should make themselves aware of the University and/or Faculty Policies regarding plagiarism, special consideration, supplementary examinations and other educational issues and student matters. Further information can be found in the Faculty Policy document available from the EEC or at:
http://www.uow.edu.au/eng/about/policies/

Plagiarism

Plagiarism will not be tolerated and has led to exclusion. Further information on plagiarism can be found in the Faculty Policy document, with full details available at:
http://www.uow.edu.au/handbook/courserules/plagiarism.html

Dr O C Kennedy
Prof T McCarthy
Dr Z Jiang

Week by week COURSE DESCRIPTION

Week	Topics	Chapter	Tutorial Problems
1	Introduction to Dynamics, Rectilinear Kinematics, Graphical Methods (in second hour of this lecture period)	12.1 - 12.3	**Yes there is a tutorial in week 1 with a practice assessment**
2	Introduction to Statics, Revision of Equilibrium, co-planar force systems, 3D force systems	1.1-3.4	**12.7**, 12.16, 12.26, 12.31, 12.44, 12.61
3	Curvilinear Motion, Rectangular Components, Projectile Motion, Normal & Tangential Components, Cylindrical/Polar Coordinates	12.4 - 12.8	**2.4**, 2.14, 3.4, 3.10, 3.26, **3.42,** 3.45, 3.75
4	Force system resultants, Moments and rotational equilibrium, revision of free body diagrams	4.1-4.10 5.1-5.4	12.83, **12.87**, 12.106, 12.120, 12.149, 12.168 **Dynamics Quiz**
5	Relative/Dependent Motion, Newton's Laws, Kinetics of Particles, Equations of Motion, Friction	12.9 - 12.10, 13.1 - 13.2, 13.4 - 13.6	**4.8**, 4.26,4.69, *4.76*[1] (4.76[2]), 4.98, 4.134, **4.144**, **5.2**,5.9, **5.12**, 5.17, 5.52 **Statics Quiz**
6	Equilibrium in 3 dimensions Trusses method of joints	5.5 6.1-6.3	**12.182**, 12.175, 12.203, 13.6, 13.15, **13.37**, 13.57, 13.66, 13.72, **13.78**, 13.93
7	Work and Energy, Conservation of Energy, Kinetic and Potential Energy	14.1 - 14.3 14.5 - 14.6	5.67, **5.75**, 5.87, **6.7**, 6.11, 6.19,
8	Trusses method of sections Internal forces, shear force, bending moment	6.4, 7.1	14.7, **14.10**, 14.15, 14.36, 14.69 (14.70[3]), **14.77**, 14.90 **Dynamics Quiz**
9	Linear Impulse and Momentum, Direct Central Impacts	15.1 - 15.7	**6.35**, 6.45, 6.46,*7.2*[1] (7.3[2]), **7.5**, 7.6, ***7.10***, (7.11[3]) **Statics Quiz**
10	Diagrams for shear force and bending	7.2 7.3	15.1, 15.23, 15.43, 15.51, 15.55 (15.56[3]), 15.64
11	Oblique Central Impact, Angular Momentum and Impulse,	15.5 - 15.7	*7.42*[1](7.42[2]), **7.47**, ***7.50***[1],(7.50[2]) *7.52*[1], (7.71[3]) 7.57, *7.61*[1](7.61[2])
12	Properties of cross sections and volumes , centre of area and centre of gravity, First and second moments of area, parallel axis theorem, moment of inertia. Product of inertia	9.1-9.5 10.1-10.6	**15.81** (15.77[2]), 15.85, **15.93**, 15.99, 15.107 (15.109[3]) **Dynamics Quiz**
13	Review of Statics and Dynamics		9.3, ***9.10***[1], 9.58, *9.64*[1](9.66[2]),9.109[4] 10.1, 10.2, 10.31, **10.40** **Statics Quiz on second moment of area see probs 10.30-10.53**

NB tutorial problems in bold & underlined (e.g. **12.7**) will be discussed in detail in the tutorial classes. Question numbers in italics are only available in 11th Edition – an equivalent question in 3rd SI edition is given in brackets.

[1] 11th Edition only
[2] Equivalent but different question in 3rd SI edition
[3] Exactly the same question in 3rd SI edition
[4] This is a challenge question for you to extend your skills.

Appendix A.2 Statics 48321 Subject Outline

UNIVERSITY OF TECHNOLOGY SYDNEY

UTS: ENGINEERING

48321: STATICS

SUBJECT OUTLINE

Subject Number:	48321
Credit Points:	6
Subject Coordinator:	Anne Gardner
Semester/Year:	*Spring 2006*
Prerequisites:	33130 Mathematical Modelling 1, 68037 Physical Modelling
Corequisites:	None
Antirequisites:	None

This subject outline contains information you will need to find your way around the subject. It attempts to provide a structure for your learning, giving details of the topics, and how, when and where you can choose to study them.

This subject outline should be read in conjunction with the relevant Faculty of Engineering Student Guide which contains information which is relevant to all Faculty of Engineering subjects. This Student Guide will contain additional relevant information.

The information in this subject outline was correct at the time of printing.

Subject Definition

The following information is drawn from the official definition of the subject which has been approved by the Faculty Board of Engineering. It will typically remain the same from semester to semester, except where variations are approved by the Faculty Board.

Subject Aims

By the end of the semester, students should be able to demonstrate development in the following areas:

- Understanding of the concept of equilibrium and its application in structural analysis
- Ability to simplify and clarify problems using free body diagrams
- Ability to analyse simple structures such as beams, trusses and pin-jointed frames subject to various loadings and support conditions
- Ability to determine internal actions in statically determinate structures and draw internal action diagrams
- Appreciation of the design process, safety factors and the issues involved in design, taking into account design constraints and the expectation to meet often conflicting design requirements
- Skill in designing axially-loaded, tensile structural members.

Contributions to overall course aims

Stages 1 & 2 - Focus on the university experience

Orient and support students as learners in the University including

- gaining an overview of professional engineering and how it is informed by academic experiences and workplace experiences
- becoming aware of different engineering fields of practice
- developing information literacy skills

starting to build the academic foundations of professional engineering education

Summary of material to be covered

- Forces and their characteristics. Scalar and vector
- Principle of transmissibilty
- Rigid bodies.
- Moments and their characteristics. Varignon's theorem
- Equivalent force/moment systems
- Centroids. Distributed loads.
- Equilibrium of rigid bodies. Free-body diagrams.
- Two force and three force body.
- Pin-jointed trusses. Method of section and method of joints. Zero force members.
- Internal actions.
- Analysis of beams. Shear force and bending moment diagrams of beams.
- Shear force and bending moment diagrams of simple frames.
- Second moment of plane areas.
- Simple stress and strain. Ultimate and allowable stresses. Factor of safety.
- Stresses at an inclined plane.
- Generalised Hooke's law.

Learning Outcomes

PROFESSIONAL FORMATION	Learning Outcomes
PF1 Values and social contexts - ability to act responsibly as a professional engineer with due regard to the social and environmental contexts of their practice	• Awareness of safety issues relating to structural design • Recognition of the duty of an engineer to be competent in analysis so as to be able to generate economical, aesthetic and safe designs
PF2 Management skills - ability to exercise sound judgement; and ability to effectively manage resources, critically appraise and work within or challenge constraints and specifications	• Ability to critically and objectively analyse structures, using sound engineering principles.
PF3 Technical expertise - ability to exercise theoretical and practical competence relevant to the intended field of practice:	• Ability to employ the principles of static equilibrium and techniques of free-body diagrams to obtain solutions to problems • Knowledge of the methods of analysis for simple, statically-determinate engineering structures.
PERSONAL DEVELOPMENT	**Learning Outcomes**
PD1 Maturity - ability to respond sensitively and critically to new environments	• Ability to apply the fundamental principles learnt in this subject to other areas of engineering
PD2 Community involvement - ability to participate as an active and informed member of society	• Recognition of the duty of an engineer to participate in issues of engineering design and safety and to warn the public when certain engineering structures become unsafe.

ACADEMIC DEVELOPMENT	Learning Outcomes
AD1 Academic literacy, numeracy, and oral comprehension and presentation skills - ability to engage critically in the academic discourse of one's discipline	• Ability to present engineering calculations in a clear and logical manner. • Ability to understand engineering diagrams and relate them to real-world situations.
AD2 Information literacy - ability to identify and satisfy knowledge needs	• Improvement in comprehending technical information and explanation.
AD3 Problem posing and solving - ability to identify, assess, and formulate problems relevant to ones academic discipline, and apply appropriate approaches and methods of problem solving	• Ability to understand the nature of mechanics problems, resolve the problem into simpler components and devise solutions for them.

Learning and Teaching Strategies

Student learning in the subject is facilitated through one three-hour lecture session followed by three-hour tutorial sessions each week. The tutorial sessions will consist mainly of discussions and problem solving. In the tutorial sessions, students are encouraged to form groups and discuss among themselves to solve the set problems, thus training them to adapt to the real-life situation where problem solving is often a group effort. Towards the end of the tutorial sessions, the tutor displays the solutions and discusses them. Individual consultation in the Learning and Design Centre is encouraged

Subject Overview

The following information is the detailed overview of the subject: including general information about the subject structure, delivery and staffing

Subject organisation and what we expect of you

The subject involves a 3 hour lecture session and a 3 hour tutorial session each week. As a student in this subject you are expected to attend and participate in all tutorials. Lectures are supported by a printed handbook of supplementary material and readings from the text. You will gain most from the lectures if you read each week's material in advance.

Tutorials are an important part of the learning experience in this subject. Students are expected to attend and participate in learning activities in all tutorials. 'End-of-topic' tests will be conducted during scheduled tutorial time.

UTSOnline will be used in this subject for announcements and to access some resource material such as answers to the tutorial problems. Some interesting links are also including on UTSOnline. I may need to contact you via email at some stage during the semester, so please ensure that your email address is correct, and make a habit of regularly looking at the UTSOnline announcements page for Statics, and your UTS email.

<NOTE: As an indication, a typical 6cp subject would normally assume a total time commitment (including class time) of approximately 150 hours, for an average students aiming to pass the subject).>

Staff

SUBJECT COORDINATOR & LECTURER	PHONE	EMAIL	OFFICE
Anne Gardner	9514-2622	Anne.Gardner@uts.edu.au	2.506

TUTORS AND OTHER STAFF	PHONE	EMAIL	OFFICE
Rezaul Karim	9514-2621	Rezaul.Karim@uts.edu.au	2.505
Rasiah Sri Ravindrarajah (Ravi)	9514-2625	Sri.Ravindrarajah@uts.edu.au	2.529

Contacting staff

If you wish to discuss your questions or need further help with understanding concepts please see the lecturer after lectures or talk to your tutor during tutorials. You can also post your question on the subject discussion board on UTSOnline. Email messages will be responded to at the earliest opportunity. Phone messages will not be responded to.

Subject timetable

Week	Lecture schedule
1 31/7/06	Introduction to Mechanics (Statics). structures and structural members. Fundamental quantities of mechanics. Vector addition and subtraction. Resultants and components of a force. Rectangular components of a force. Resultants using these. Text Ch. 1, & Ex. 1.
2 7/8/06	Statics of Particles: free-body diagrams, equilibrium: two dimensional problems. 2 D Rigid Bodies: Principle of Transmissibility, moment of a force, Varignon's theorem, couples, equivalent force/couple systems. Text 1.5.2, 1.5.3 2.1 – 2.5.
3 14/8/06	Load paths. Idealisation of supports and connections for 2D bodies. Free body diagrams. Equilibrium of 2D bodies. Text Ch. 1.5.5, Ex. 3, Ch. 2.6. Equilibrium of 2D bodies – checking answers using a different set of equations. Equilibrium of 2 and 3 force bodies. Statically indeterminate systems- partial and improper constraints. Text 2.7.
4 21/8/06	Analysis of pin-jointed frames – three pin arches. Text Ch. 2.8, Discussion Ex. 2.1. Types of beams. Distributed loads: types, equivalent loads. Equilibrium of a 2D structure subjected to distributed loads. Text Ch. 1.5.3.
5 28/08/06	Pin-jointed trusses – definition, examples, simple and compound. Method of joints. Text Ch. 3.1 – 3.3, Ex. 4. Method of sections. Special loading conditions – zero force members, counters. Analysis of compound trusses. Text Ch. 3.3.2, Ex. 5 & 6.6.4.
6 4/9/06	Simple stress and strain – uniaxial and shear, Young's modulus, Hooke's Law, Axial deflection, Poisson's ratio. Ch. 3.4.1 – 3.4.4, Ex. 6 & 7. Factor of safety, ultimate and allowable stress. Limit State Design Philosophy.
7 11/9/06	Introduction to Euler buckling. Introduction to mechanics of solids. Properties of areas – centroid, first moment, second moment of area. Text 4.7, 4.8 & 5.1. Parallel axis theorem. Composite areas. Text Ch. 5.2, Ex. 14, Discussion Ex. 5.1 & 5.2.
8 18/9/06	Introduction to internal actions. Calculating internal actions using equilibrium. Effect of crossing a load or moment. Text Ch. 4.1 & 4.2 Equations of internal actions from free body diagrams.
25/9/06	VICE CHANCELLOR'S WEEK
9 2/10/06	TUTORIAL WEEK
10 9/10/06	Diagrams of internal actions in straight beams – effects of external concentrated and distributed loads, applied moments and support conditions. Text Ch. 4.3 & 4.4, Ex. 9 & 10. Internal action diagrams for straight beams- 4 representative loading cases. Discussion Exercises 4.1 – 4.4.
11 16/10/06	Internal action diagrams for straight beams Internal action diagrams for simple frames. Internal action diagrams for bent beams. Discussion Exercises 4.5 & 4.6.
12 23/10/06	Derive $dV/dx=-\omega$ and $dM/dx=-V$. Equations of shear and bending moment using these. Text Ch 4.5. Drawing shear force and bending moment diagrams using $dV/dx=-\omega$ and $dM/dx=-V$. Exercise 11. Discussion Exercise 4.7.
13 30/10/06	Revision
14 6/11/06	Revision. Past Exam Papers and Text competency exercises.

A site visit to Australian Technology Park will be organised during the semester. This is currently scheduled for Friday 1st September during normal tutorial time (11am – 2pm). This will be confirmed closer to the date.

Assessment

IMPORTANT NOTE: This should be read in conjunction with the information on assessment in both the student guide and in the UTS Coursework Assessment procedures and policy manual.

The details of all aspects of assessment (including, but limited to, submission processes, late penalties, referencing, attendance, etc.) are governed by the details in these associated documents except where explicitly over-ridden by the following information.

Assessment tasks

Assessment	Nature of task	Purpose	% weighting
Special Project	Report on a structural support or element	• To provide practice to students on applying subject concepts to real structures	5
Regular assignments	Solve set problems	• To provide additional practice to students on problem solving. • To bring students up to date with material already covered in lectures so that students can understand subsequent lectures better.	10
Topic Tests – best 6 of 7 counted	1 hour duration quizzes on problem solving	• To allow students to determine if they understand the topic covered with time to apply corrective measures before the final exam	25
Final Examination	3-hour duration exam. on all the material covered during the semester	• Validation of learning on the fundamental concepts of statics and their application to solve problems	60

The regular assignments can be completed and submitted as group assignments. For the purpose of these assignments a group is allowed to contain no more than four students and theses four students must be from the same tutorial group. Students may choose to submit these regular assignments individually – the choice is yours. However, if two submitted assignments appear to be the same, the Faculty's policy for dealing with plagiarism/academic misconduct will be initiated.

The 'Special Project' is NOT to be submitted as a group task, it is an individual effort. The 'end-of-topic' tests and the final examination are also individual submissions. Any copying or other forms of cheating observed during these tests will be dealt with severely according to the Faculty's policy on academic misconduct.

Minimum essential requirements for students

In order to pass the subject, you must

> earn 50% or more of the marks for the regular assignments and the Special Project; **and**
> earn more than 50% overall for the student's best 6 of 7 'end-of-topic' tests
> earn more than 50% in the final examination; **and**
> earn an overall total of 50 marks or more for the subject.

Assessment procedures and advice

Information on general Faculty policy about assessment procedures etc. is provided in the Faculty Student Guide. The following information is provided in addition to this, and covers any variations to the defaults in the course guide.

Specific information about who to submit your assignments to will be provided in lectures before the first assignment is due. Late assignments will not be accepted, except in special circumstances.

Students are expected to submit assignments that comply with the following:

- Presentation should be reasonable neat and orderly throughout. Take pride in your work. (I need to be able to read it to mark it.)
- The work should be able to be understood by another student engineer without having to refer to any other document. Diagrams are essential in almost every problem.
- The problem posed should be concisely stated and the solution clearly indicated.
- Units MUST be given throughout.
- Where the problem involves finding forces and/or couples, these should be clearly shown including their direction.
- Use A4 size paper and staple sheets together.
- DO NOT USE PLASTIC ENVELOPES OR BINDERS
- Be sure your name and student no. are on the cover page
- If you had difficulty answering a problem, please comment at the end of your answer.

Please note that any submitted work that is clearly scrappy, or difficult to follow will not be marked and will receive no assessment credit.

Learning resources

Learning guide

Some learning resources for this subject are available in the Learning and Design Centre 2 (LDC2) on level 6 of building 2. These include a copy of the textbook and some of the reference books listed below. Worked solutions to questions in the 'Statics Tutorial Problems' booklet are also available in LDC2.

Required texts

Lemass B. and Gardner A., **Fundamental Structural Analysis for Design**, 2005. Pearson Prentice Hall, NSE. ISBN 0733969879

References and Internet Sites

Hibbler R.C. **Engineering Mechanics – Statics,** SI edition 3rd edition, 2004. Pearson Prentice Hall ISBN 0131248448

Meriam J.L. and Kraige L. G. **Engineering Mechanics (Volume 1) – Statics**, 5th edition 2003. John Wiley and Sons, Inc.

Beer F.P. and Joohnston E.R. **Mechanics for Engineers – Statics**, 4th edition McGrawHill International

UTS-Online

All students will have an account on the Statics site on UTS Online. All students are expected to check this site at least once each week for any Announcements. Subject staff will rely on students' email address registered on UTS Online for out of class official communication during the semester. It is therefore imperative that students ensure that their current email address is registered on UTS Online, and that they check their email account at least once a week.

Appendix A.3 KNE112 Subject Outline

UNIVERSITY OF TASMANIA

School of Engineering

Faculty of Science, Engineering and Technology

KNE112

Engineering Mechanics

Second Semester, 2007

Unit Outline

Dr Alan Henderson

Professor Chris Letchford

Contact details

Unit coordinator/lecturer

Unit coordinator/lecturer:	Dr Alan Henderson
Campus:	Hobart
e-mail:	alan.henderson@utas.edu.au
Phone:	(03) 6226 7639
Fax:	(03) 6226 7247
Room number	216
Consultation hours:	See Office Door

Other teaching staff

Lecturer	Professor Chris Letchford
Campus:	Hobart
e-mail:	chris.letchford@utas.edu.au
Phone:	(03) 6226 2135
Fax:	(03) 6226 7247
Room number	327
Consultation hours:	See Office Door

Tutor	Mr Steffen Oberstein
Campus:	Hobart
e-mail:	steffen.oberstein@utas.edu.au
Room number	323
Consultation hours:	See Office Door

Contents

Unit description

The main objective of this unit is to develop in students the ability to analyse engineering mechanics problems in a simple and logical manner through the application of a few well-understood basic principles. It will extend the fundamental concepts of Newton's Mechanics learnt by the students in physics courses during their college studies. It also aims at giving students the necessary background for learning skills to design, construct, and supervise real engineering projects.

The unit covers fundamental concepts and principles of engineering mechanics (Statics and Dynamics). It builds on the material covered in KNE121 Engineering Profession and Industry. The unit is a pre-requisite for KNE212 Mechanics and Structures, a core unit to Civil, Mechanical, Mechatronic and Civil/Mining specialisations.

Learning outcomes

Learning outcomes include the development of skills in and understanding of:

- Vector arithmetic
- Statics of particles
- Rigid bodies: Equivalent systems of forces
- Equilibrium of rigid bodies, calculation of reactions
- Distributed forces: Centres of gravity and centroids
- Kinematics of particles
- Kinetics of particles: Newton's second law
- Kinetics of particles: Energy and momentum methods
- Friction

Generic graduate attributes

The University has defined a set of generic graduate attributes (GGAs) that can be expected of all graduates (see http://www.utas.edu.au/tl/policies/index.htm). By undertaking this unit you should make progress in attaining the following attributes:

Knowledge:

- ability to apply knowledge of basic science and engineering fundamentals;
- in-depth technical competence in at least one engineering discipline;

Communication skills:

- ability to communicate effectively, not only with engineers but also with the community at large;

Problem-solving skills:

- ability to undertake problem identification, formulation and solution;

Prior knowledge &/or skills

A background in physics and mathematics applicable to solving engineering mechanics problems. This includes vector arithmetic, trigonometry, and calculus.

Prerequisites

- KNE121 Engineering Profession and Industry.

Learning resources required

Requisite texts

- Beer FP and Johnston ER Jr, *Vector Mechanics for Engineers, Statics and Dynamics*, 7^{th} Edition, McGraw-Hill, 2004

Note this text forms the basis for KNE212 Mechanics and Structures, a core unit to Civil, Mechanical, Mechatronic and Civil/Mining specialisations, and also for KNE352 Dynamics Systems (Mechanical and Mechatronic Specialisations).

It comes with a suite of excellent learning resources described below. Students are strongly encouraged to purchase it.

The online material associated with the required text includes access to:

1. S.M.A.R.T. (Self-Paced, Mechanics, Algorithmic, Review, Tutorial),
2. Multiple-choice quizzes,
3. The Statics and Dynamics Design Center
4. Access Science - an online resource that contains articles, dictionary terms and research updates in all areas of science and technology.

E- (electronic) resources

Solutions to weekly tutorial problems will be made available on the Engineering School server after 12 noon Friday of the following week. This page can be accessed through the UTAS web site: http://www.eng.utas.edu.au/subjects.

Library

Several copies of the requisite text book will be available in the Science Library.

Details of teaching arrangements

Lectures/Intensive sessions

Three 1 hour Lectures will be delivered each week, with exception to weeks 4, 8 and 12 where there will be two 1-hour lectures and 1 quiz. Lecture times in week 13 will be used for revision.

Tutorials

Weekly tutorials will be used to support lecturing and are designed to give students the opportunity to reflect on material covered in lectures, develop problem solving skills and also provide necessary feedback on their understanding of the course. Previous experience has shown that students who work through problems usually do well in the final examination. Solutions will be placed on the engineering server after 12 noon one week following the due date.

Quizzes

Three written quizzes will be held during semester. These are designed to give students feedback on their understanding of the course while working under a time constraints. Students should bring pens/pencils and a non-programmable scientific calculator. Adequate space for answers will be provided on the question sheets.

Field trip

A field trip will be announced during semester. The aim of this is to provide show students interesting and relevant applications of engineering design. For those unable or unwilling to attend the field trip a 2000 word essay on a topic selected by the lecturers will be required to be submitted within one week of the field trip.

Occupational health and safety (OH&S)

The University is committed to providing a safe and secure teaching and learning environment. In addition to specific requirements of this unit you should refer to the University's policy at: http://www.admin.utas.edu.au/hr/ohs/pol_proc/ohs.pdf.

The School of Engineering issues a document to all students outlining its OH&S policy for the School's Laboratories and Workshops. It is a requirement that all students must have read this document prior to entering any of the School's workshops or laboratories.

Unit schedule*

Week	Date beginning	Topic	Readings / Resources
1	16 July	Introduction; Statics of particles : forces as vectors, equilibrium of a particle	Chapters 1 & 2
2	23 July		
3	30 July	Rigid bodies: moments, couples and equivalent systems of forces	Chapters 3
4	6 August		
4	**10 August**	**QUIZ 1**	
5	13 August	Rigid bodies: equilibrium in two and three dimensions	Chapters 4
6	20 August		
7	27 August	Distributed forces : centroids and first moments; Friction	Chapters 5
	Mid-semester break		
8	10 Sept	Forces in beams, support types, bending moment and shear force diagrams	Chapter 7
8	**14 Sept**	**QUIZ 2**	
9	17 Sept	Particle Kinematics : rectilinear motion, uniformly accelerated motion, curvilinear motion	Chapters 11
10	24 Sept		
11	1 Oct	Particle Kinetics : equations of motion, angular momentum, work, energy and power, impulse and momentum	Chapters 12 & 13
12	8 Oct		
12	**12 Oct**	**QUIZ 3**	
13	15 Oct	Revision	

*The unit schedule above may alter to accommodate conflicts with other University duties.

Learning expectations and strategies

Expectations

The University is committed to high standards of professional conduct in all activities, and holds its commitment and responsibilities to its students as being of paramount importance. Likewise, it holds expectations about the responsibilities students have as they pursue their studies within the special environment the University offers.

The University's Code of Conduct for Teaching and Learning states:

> *Students are expected to participate actively and positively in the teaching/learning environment. They must attend classes when and as required, strive to maintain steady progress within the subject or unit framework, comply with workload expectations, and submit required work on time.*

Learning strategies

Attending lectures is highly recommended. The material covered in lectures will not be made available in electronic form. A bullet point summary of relevant content may be provided in some cases – but this will not be complete lecture notes.

If you do not understand something in lectures or tutorials, please ask for clarification in the lecture if need be, or immediately after the lecture if your question can wait until then. *Asking questions is part of the learning process and it is strongly encouraged.*

Participation in tutorials is strongly recommended. Previous experience has shown that students who work through problems usually do well in the final examination. Just looking at how someone else solved a problem does not develop your understanding or problem solving skills, and will help you little in the exam. You should use tutorial time most efficiently by working on the scheduled tutorial (as opposed to the previous one), and asking your tutor questions.

If you need assistance in preparing for study please refer to your tutor or lecturer. For additional information refer to the Learning Development website : http://www.utas.edu.au/learndev/

Specific attendance / performance requirements

The Faculty of Science, Engineering and Technology states that all students must attend a minimum of 2/3rds of all lectures and tutorials. This policy may be viewed at http://fcms.its.utas.edu.au/files/policies/Faculty%20Assessment%20Guidelines%20Nov%202004(1).pdf

The site visit is mandatory for all students. Students that fail to attend without being granted an exemption must pass an alternative assessment task in order to pass the unit. The additional assessment task will comprise of a 2000 word essay on a topic set by the lecturers.

Assessment

The assessment will comprise of the following tasks:

- 3 quizzes (each worth 6%) = 18%
- 12 weekly tutorials (each worth 1%) = 12%
- One 3 hour end of semester Exam = 70%

Assessment schedule

Assessment task	Date due	Percent weighting
Tutorial 1	23 July	1
Tutorial 2	30 July	1
Tutorial 3	6 August	1
Quiz 1	10 August	6
Tutorial 4	13 August	1
Tutorial 5	20 August	1
Tutorial 6	27 August	1
Tutorial 7	10 Sept.	1
Quiz 2	14 Sept.	6
Tutorial 8	17 Sept.	1
Tutorial 9	24 Sept.	1
Tutorial 10	1 Oct.	1
Tutorial 11	8 Oct.	1
Quiz 3	12 Oct.	6
Tutorial 12	15 Oct.	1
End of semester exam		70

How your final result is determined

Your final result will be determined from the aggregate of the internal assessment results (tutorials and quizzes) with the results from the end of semester exam.

Submission of assignments

Tutorials should be submitted to the KNE112 assignment box located adjacent to the School of Engineering Office.

Requests for extensions

All requests for extensions should be submitted via email to Dr Henderson WELL BEFORE the due date of the assignment (alan.henderson@utas.edu.au). Generally, foreseeable work commitments will not be grounds for an extension.

Penalties

Unless an extension has been granted in writing, a penalty of 20% of the awarded mark will be deducted for each business day the tutorial is overdue. Tutorials more than 5 business days late will not be marked.

In cases where a word limit has been specified, submissions that exceed the word limit by more than 10% are likely to incur a penalty of 10% of the awarded mark for each 10% over the word limit.

Review of results and appeals

Appeals should go to the Unit Coordinator (i.e. Dr Alan Henderson) in the first instance. If unresolved, appeals are referred to the First Year Coordinator (i.e. Dr David Wood) and, if necessary, to Faculty of Science, Engineering and Technology.

Academic referencing

In your written work you will need to support your ideas by referring to scholarly literature, works of art and/or inventions. It is important that you understand how to correctly refer to the work of others and maintain academic integrity.

Failure to appropriately acknowledge the ideas of others constitutes academic dishonesty (plagiarism), a matter considered by the University of Tasmania as a serious offence.

The required referencing style for this unit is APA. The Library has information about how to reference in this style

http://www.utas.edu.au/library/info/subj/education.html

Please read the following statement on plagiarism. Should you require clarification please see a unit coordinator or lecturer.

Plagiarism

Plagiarism is a form of cheating. It is taking and using someone else's thoughts, writings or inventions and representing them as your own; for example, using an author's words without putting them in quotation marks and citing the source, using an author's ideas without proper acknowledgment and citation, copying another student's work.

If you have any doubts about how to refer to the work of others in your assignments, please consult your lecturer or tutor for relevant referencing guidelines, and the academic integrity resources on the web at http://www.utas.edu.au/tl/supporting/academicintegrity/index.html.
The intentional copying of someone else's work as one's own is a serious offence punishable by penalties that may range from a fine or deduction/cancellation of marks and, in the most serious of cases, to exclusion from a unit, a course or the University. Details of penalties that can be imposed are available in the Ordinance of Student Discipline – Part 3 Academic Misconduct, see http://www.utas.edu.au/universitycouncil/legislation/

The University and any persons authorised by the University may submit your assessable works to a plagiarism checking service, to obtain a report on possible instances of plagiarism. Assessable works may also be included in a reference database. It is a condition of this arrangement that the original author's permission is required before a work within the database can be viewed.

For further information on this statement and general referencing guidelines, see http://www.utas.edu.au/plagiarism/ or follow the link under 'Policy, Procedures and Feedback' on the **Current Students** homepage.

Further information and assistance

If you are experiencing difficulties with your studies or assignments, have personal or life planning issues, disability or illness which may affect your course of study, you are advised to raise these with your lecturer in the first instance.

There is a range of University-wide support services available to you including Teaching & Learning, Student Services, International Services. Please refer to the ***Current Students*** homepage at: http://www.utas.edu.au/students/

Should you require assistance in accessing the Library visit their website for more information at http://www.utas.edu.au/library/

Appendix A.4 KNT112 Subject Outline

AUSTRALIAN MARITIME COLLEGE

Unit Specification

Unit Code: E03 183 ***Unit Title:*** Engineering Mechanics

Semester: 2 ***Year:*** 2007

Course: Bachelor of Engineering

(Naval Architecture, Ocean Engineering, Marine & Offshore Systems, UTas)

Dept/Sch: Department of Maritime Engineering

Campus: Newnham

Fraction of an EFTSL[1]: 0.125

Academic Staff:

Title	Name	Office	Email	Phone	Consultation days & times
Lecturer & Co-ordinator	Dr. Christopher Chin	G59	c.chin@amc.edu.au	6335 4441	TBA
Laboratory Lecturer	Dr. Hung Nguyen	G62	H.Nguyen@amc.edu.au	6335 4350	TBA

Aim of the Unit:

- To provide students with the ability to predict the effects of forces and moments on simple determinant structures and mechanisms.

- To provide students with the ability to determine and identify various machine motions, and their force and torque effects, particularly in terms of the kinematics and kinetics of solid rotating and translating members, and the mechanical transmission of power.

Learning Outcomes:

On successful completion of this unit, students should be able to:

- Resolve a system of forces and moments into a central force and moment.
- Calculate the acceleration of an object under the influence of a system of forces and moments.
- Construct angular velocity and acceleration diagrams for simple mechanisms.
- Calculate the moment of inertia of simple geometric bodies.
- Calculate velocities and maximum forces resulting from an in-line impact.
- Find, both analytically and graphically, the linear and angular accelerations of members moving in general plane motion.
- Select simple motion transmission systems.
- Explain and calculate stress and strain for one dimensional systems.
- Explain simple harmonic motion and calculate the basic properties.

Primary Delivery Mode: **On Campus**

Web-CT: No

[1] Effective Full Time Student Load, e.g. if a program has 8 units in a year and all units are of equal size then each one is 1/8 = 0.125 EFTSL

Teaching and Learning Approaches:

Lectures, tutorials, quizzes, class test, assignment and team based experimental investigation

Text Books:

Hannah, J. & Hillier, M.J., *Applied Mechanics*, 3rd edition, Longman, England, 1998.

Reference Texts:

Embleton, W. & Jackson, L., *Applied Mechanics for Engineers*, Thomas Reed, UK, 1994.
Hannah, J. & Stephens, R. C., *Mechanics of Machines*, Edward Arnold, London, 1979.
Kinsky, R., *Engineering Mechanics and Strength of Materials*, McGraw Hill, Sydney, 1992.
Mabie, H,H., and Reinholtz, C. F., *Mechanisms and Dynamics of Machinery*, Wiley.
Stephens, R. C., *Strength of Materials*, Edward Arnold, London, 1974.
Ryder, G.H., and Bennett, M.D., *Mechanics of Machines*, Macmillan Education Ltd., London, 1975.

Required Materials:

Non-programmable scientific calculator, geometry box.

Extra Costs:

Bound class notes to be purchased from Students Association shop at nominal cost.

Materials to be provided by AMC:

Extra handouts to supplement the class notes where necessary.

Health and Safety requirements:

Students are required to obey AMC's Occupational Health and Safety (OH&S) regulations.

Students must provide and use Personal Protective Equipment (PPE) for their own protection against risks. During Lab sessions, students must wear Steel-capped safety boots, lab-coats (or overalls), clear safety glasses with side ingression protection, UV protection, and a full hair restraint if possessing long hair.

Food and beverages are not allowed in classrooms and labs.

Class times:

Class	Day	Time	Locations
Lectures	Thursdays	9:00-9:50am	Auditorium
	Thursdays	10:00-10:50am	Auditorium
	Thursdays	11:00-11:50am	Auditorium
Tutorials	Thursdays	1:10-2:00pm	G71/72
	Thursdays	2:10-3:00pm	G71/72
Practicals	TBA	TBA	G53 (Mechanics Lab)
	TBA	TBA	G53 (Mechanics Lab)

Note: Students need to attend only one of the two tutorials listed in the above table. The class list with the times that the student should be attending the tutorials is posted on the notice board on the ground level near the computer labs in Swanson building. If students could not attend the tutorials due to clashes and wish to change their time slot, please see the lecturer ASAP.

Attendance Requirements:

Attendance at lab sessions is compulsory.

Attendance at all assigned class times is expected. You are responsible for all information (both academic and administrative) presented during class times. Should you miss a class for whatever reason it is your responsibility to obtain information and content that was missed.

Syllabus:

1. **Forces and Moments**
   Force systems, resolution of forces, force polygons, moments and couples, equilibrium and free body diagrams. Force analysis in simple machines and structures. Method of joints to analyse simple structures.

2. **Motion**
   Newton's laws of motion. Motion diagrams, linear motion, motion under gravity, and projectiles.
   Rotational motion, inertia forces, centrifugal and centripetal acceleration, friction forces, flywheels, and governors.

3. **Stress and Strain (one dimensional)**
   Tensile, compressive and shear stress and strain, Hooke's law, factor of safety, and thermal stresses.

4. **Energy and Momentum**
   Work and power, energy of linear and rotating systems, strain energy, and principles of conservation of energy.
   Linear and angular momentum, impulse, principle of conservation of momentum, collision of two bodies, and impact forces.

5. **Kinematics of Rigid Bodies**
Degrees of Freedom of mechanisms. Velocity and Acceleration diagrams for mechanisms, and slider-crank mechanisms.

6. **Mechanical Power Transmission**
Belt and chain drives. Transmission through friction clutches using various shaft bearing types, and via spur, bevel, worm, epicyclic gear trains. Balancing of rotating masses.

7. **Simple Harmonic Motion**
Linear and rotary harmonic motion, inertia, stiffness, damping, natural frequency, period, and resonance.

Investigative Studies:

The investigative studies will cover areas such as: moment of inertia of rotating masses; conservation of energy and momentum; disc and belt friction; gear trains; brakes and clutches; mechanisms; and the design of basic power systems and machine components.

Learning Schedule:

Weeks	Dates	Lectures Thursdays 9:00-9:50am	Lectures Thursdays 10:00-10:50am	Lectures Thursdays 11:00-11:50am	Tutorials Thursdays	Assessment / Lab
1	16 – 20 July	Section 1 Forces and Moments	Forces and Moments	Forces and Moments		Assignment handed out
2	23 – 27 July	Forces and Moments	Forces and Moments	Section 2 Velocity and Acceleration	Forces and Moments	
3	30 July – 3 August	Velocity and Acceleration	Velocity and Acceleration	Velocity and Acceleration	Quiz 1 (Forces and Moments & Velocity and Acceleration)	
4	6 – 10 August (10 Aug:Census date – Sem 2)	Section 3 Friction Forces	Friction Forces	Section 4 Equations of Motion, Energy and Power	Friction Forces	
5	13 – 17 August	Equations of Motion, Energy and Power	Equations of Motion, Energy and Power	Equations of Motion, Energy and Power	Equations of Motion, Energy and Power	
6	20 – 24 August	Class Test (Section 1, 2, 3 and 4)	Class Test (Section 1, 2, 3 and 4)	Section 5 Stress and Strain	Stress and Strain	
7	27 – 31 August	Stress and Strain	Stress and Strain	Stress and Strain	Quiz 2 (Stress and Strain)	
8	10 – 14 September (Semester break: 3 – 7 Sept)	Section 6 Thermal Expansion and Stresses	Thermal Expansion and Stresses	Thermal Expansion and Stresses	Thermal Expansion and Stresses	
9	17 – 21 September	Section 7 Kinematics of Mechanisms	Kinematics of Mechanisms	Kinematics of Mechanisms	Quiz 3 (Thermal Expansion and Stresses)	Assignment due 20th September 2007 at 3PM
10	24 – 28 September	Kinematics of Mechanisms	Kinematics of Mechanisms	Kinematics of Mechanisms	Kinematics of Mechanisms	
11	1 – 5 October (7 Oct: Daylight saving begins)	Section 8 Balancing Rotating Masses	Balancing Rotating Masses	Balancing Rotating Masses	Balancing Rotating Masses	
12	8 – 12 October	Section 9 Simple Harmonic Motion	Simple Harmonic Motion	Simple Harmonic Motion	Quiz 4 (Balancing Rotating Masses & Simple Harmonic Motion)	
13	15 – 19 October	Revision	Revision	Revision	Revision	

Assessment:

Types and Weighting of Assessment:

Coursework	Unit Mark %	Week	Examination	Unit Mark %
Quizzes	10	3, 7, 9, 12	Final Examination (3 hours)	60
Class Test	15	6		
Assignment	15	9		
Coursework Total:	**40%**		**Examination Total:**	**60%**
		Combined Total: **100%**		

To pass this unit, a student must achieve a minimum of **50% in the coursework**, a minimum of **50% in the final examination**, and achieve an overall average of **50% for the unit.**

In addition, to pass the unit, all laboratories must be successfully completed and be awarded a grade of Pass.
Attendance at all laboratory and practical sessions is compulsory.

Exam (60%). Students are responsible for material from lectures, tutorials and practicals. A 3-hour exam in October/November will cover all aspects of the unit. The primary emphasis will be (i) problem identification, formulation and solution and (ii) demonstration of basic fundamentals. **The exam schedule will be finalised several weeks before the examination period. Do not make travel plans until the exam schedule is finalised.**

Class Test (15%). One class test (closed book) is scheduled throughout the semester (see Syllabus and Learning Schedule). On the scheduled week, the class test will fall during the lectures unless otherwise advised. Although correct answers are important, clear communication of what you did and how you did it is equally important.

Assignment (15%). One assignment is scheduled throughout the semester. The assignment is to be done individually and the completed assignment is to be typed out using a word processor. Students are to follow the layout of the assignment which will be discussed in the lecture.

Quizzes (10%). Four quizzes are scheduled throughout the semester (see Syllabus and Learning Schedule). On the scheduled week, the quiz will fall during the tutorials unless otherwise advised. Students are expected to submit each of these 4 quizzes at the end of each class for assessment. The completed quizzes will be returned as soon as they are marked. Apart from the bound class notes purchased from the SA shop, no other materials (such as textbook and/or unauthorised notes/solutions) are allowed in any of the quizzes. No communication between students is allowed during these 4 quizzes. Each of the 4 quizzes contributes 2.5% towards the final assessment. Each of these quizzes are designed to address the learning outcomes, starting with the basic skills that students must first acquire through lectures and out-of-class practice in order to be competent to solve more complicated problems in the later stage of the course. Although correct answers are important, clear communication of what you did and how you did it is equally important.

Tutorials. Tutorials are as per timetable and attendance is compulsory. Eight tutorials are scheduled throughout the semester (see Syllabus and Learning Schedule).

Practicals (Pass/Fail). The practicals require **preparation, participation and individual reporting**. The format for the reports will be discussed prior to the first submission. Practical reports, teamwork and written and graphical communication skills will be emphasised and assessed. All practicals are to be typed out using a word processor. **Participation is assessable so attendance is mandatory**. Problem lay out and written communication skills are very important in engineering problem solving. Teamwork and leadership will also be stressed.

To pass the practical component, a student must attend all lab sessions and submit a satisfactory lab report for each practical.

Submission of assignment and practicals:

The completed assignment and practicals are to be submitted to the Division, Academic & Research Office (1st floor Swanson Building) together with a mandatory cover sheet. Electronic submissions are not acceptable.

Final grade:

The grade that you receive for this unit will be determined by a committee of examiners. The raw marks that you receive from each piece of assessable material will be combined in order to determine a letter grade for the unit. The raw marks may undergo a scaling process to ensure meeting AMC policies on the distribution of grades.

Problems with your assessment:

If you have questions or problems with your assessment, you should undertake discussion with the following people until you have received a resolution of the issues. (1) The person who marked the assessment. (2) Unit Coordinator. (3) Head of Department/School in charge of the unit. (4) Vice-President (Academic & Research) – Professor Tom Hardy. If this does resolve the issue you may file formal appeal by contacting the office of the Registrar.

Student Support:

Some students will have problems that will affect learning that can span a wide range of family, relationship, health, emotional, financial and educational issues. AMC has support systems, but it is important that you recognise that you have a problem and seek help promptly before your learning is irreparably hampered. The student support offices at Newnham campus are located above the library. For a description of the support available at AMC please see http://www.amc.edu.au/students/student.support/ .

Appendix B.1 UOW HREC Approval HE08/017

University of Wollongong

DOCUMENT NOTED
In reply please quote: HE08/017
Further Enquiries Phone: 4221 4457

11 March 2008

Mr T Goldfinch
Faculty of Engineering
University of Wollongong

Dear Mr Goldfinch

I am pleased to advise that the information document listed below relating to the following Human Research Ethics application has been noted and confirm that the Human Research Ethics application referred to below has been approved.

Ethics Number:	HE08/017
Project Title:	A Multi-Institution Approach to Predicting and Addressing Student Performance in Fundamental Engineering Mechanics.
Document/s:	Copy of application form signed by Head of Department
Name of Researchers:	Mr T Goldfinch, Professor T McCarthy, Dr A Carew, Dr G Thomas, Ms A Gardner, Dr A Henderson

Yours sincerely

P.A. Potter

PP A/Professor Garry Hoban
Chairperson
Human Research Ethics Committee

Research Services Office University of Wollongong NSW 2522 Australia
Telephone: +61 2 4221 3386 **Facsimile:** +61 2 4221 4338
research_services@uow.edu.au www.uow.edu.au/research
CRICOS Provider No: 00102E

Appendix B.2 UTS HREC Ratification

03 June 2008

Ms Anne Gardner
CB02.05.06
Infrastructure and the Environment
Faculty of Engineering
UNIVERSITY OF TECHNOLOGY, SYDNEY

Dear Anne,

UTS HREC REF NO 2008-131 – GARDNER, Ms Anne, MCCARTHY, Professor Timothy, GOLDFINCH, Mr Thomas - "A Multi-Institutional Approach to Predicting and Addressing Student Performance in Fundamental Engineering Mechanics"

Thank you for your response to my email dated 16 May 2008. Your response satisfactorily addresses the concerns and questions raised by the Committee, and I am pleased to inform you that ethics clearance is now granted.

Your clearance number is UTS HREC REF NO. 2008-131A

Please note that the ethical conduct of research is an on-going process. The *National Statement on Ethical Conduct in Research Involving Humans* requires us to obtain a report about the progress of the research, and in particular about any changes to the research which may have ethical implications. This report form must be completed at least annually, and at the end of the project (if it takes more than a year). The Ethics Secretariat will contact you when it is time to complete your first report.

I also refer you to the AVCC guidelines relating to the storage of data, which require that data be kept for a minimum of 5 years after publication of research. However, in NSW, longer retention requirements are required for research on human subjects with potential long-term effects, research with long-term environmental effects, or research considered of national or international significance, importance, or controversy. If the data from this research project falls into one of these categories, contact University Records for advice on long-term retention.

If you have any queries about your ethics clearance, or require any amendments to your research in the future, please do not hesitate to contact the Ethics Secretariat at the Research and Innovation Office, on 02 9514 9615.

Yours sincerely,

Dr Chris Zaslawski
Acting Chairperson
UTS Human Research Ethics Committe

Appendix B.3 UTAS HREC Ratification

H9967

Tasmania
DEPARTMENT of HEALTH and HUMAN SERVICES

Human Research Ethics Committee (Tasmania) Network

UTAS

Social Sciences Ethics endorsement for

PRIOR APPROVAL APPLICATIONS

For researchers who are participating in a research project that already has approval from a fully constituted Australian ethics committee, there is no need to complete an HREC (Tasmania) application. Please complete this document and attach the original ethics application, final approval letter and other documents as indicated in Section 2.

Please send the signed hard copy in the mail with the attachments to
Marilyn Knott, Ethics Officer, Research Services, Private Bag 01, University of Tasmania, 7001

SECTION 1 – Researchers

Title of Research A Multi-Institution Approach to Predicting and Addressing Student Performance in Fundamental Engineering Mechanics

University School: School of Engineering, Maritime Engineering and Hydrodynamics

University of Tasmania Investigator's Name: Dr Anna Carew

Phone 63354723
Email anna.carew@utas.edu.au
Signature A. Carew

Other UTas Investigator	Details	Status
Name	Dr. Alan Henderson	
Phone	62267639	
Email	alan.henderson@utas.edu.au	
Signature	A Henderson	

Other UTas Investigator	Details	Status
Name	Dr. Giles Thomas	
Phone	63354883	
Email	G.thomas@utas.edu.au	
Signature		

By signing the above, all investigators are confirming the following statements:

1. I confirm that I have read and abide by the principles as explained in the *National Statement on Ethical Conduct*

Involving Humans (NH&MRC)

2. I undertake to use the data and information collected in the research only for the purposes of the research, to make no unauthorised disclosure of that data or information, and to maintain the anonymity of all participant data except pursuant to the express consent of the relevant participant(s).

SECTION 2 – ATTACHMENTS

✓	Copy of the Application
✓	Copy of the final approval letter
✓	Copy of all approved documentation (eg information sheets, consent forms, surveys, etc)

SECTION 3 - DATA STORAGE

Indicate the location at which the data will be retained.	Exam transcripts will be kept in locked storage on UTas premises, as per standard policy. Other analysis data will be kept in locked storage in the office of Mr. Thomas Goldfinch at the University of Wollongong for the period of the research. Upon completion of the research, UTas data will be returned to locked storage in the offices of Dr. Henderson, and Dr. Thomas for a period of five years.

Appendix C.1 UOW MRMF Question Analysis Spreadsheet

Knowledge Categories			
	A. Concrete associations	B. Verbal information	C. Fact systems
1. Concrete Facts		• Units • Terminology	• Identifying force/momentum components • Units • Sign conventions • Determining tension or compression • Equations for calculating second moment of area
	A. Linear Procedures	B. Multiple discriminations	C. Algorithms
2. Procedures	• Calculating kinetic energy • Calculating potential energy • Calculating Impulse • Calculating momentum • Calc. of vectors (unit or pos) • Calculating second moment of area for complex shape • Area of circle	• Summation of forces (Q6b) • identifying/calculating velocity from potential energy • Oblique impact analysis • Calculating moments using vectors • Calculating components of moments using vectors • Calculating Reaction Forces • Shear force Diagrams • Bending moment Diagrams • Use of trigonometry/components in force calculations	• Method of sections
	A. Concrete concepts	B. Defined concepts	C. Concept systems
3. Concepts		• Kinetic energy • Conservation of momentum • impulse • Normal acceleration • Coordinate interpretation • Unformly distributed loads (and conversion to pt load) • 2nd moment of area for complex shape (ie. Dist. Form centroid etc.)	• Restitution impulse • Free body diagrams • Relationship between force and other vectors to determine moments • Free body diagrams • Internal forces - Shear Force • Internal forces - Bending Moment
	A. Rules of nature	B. Rules of action	C. Rule Systems
4. Principles	• Conservation of Momentum • Conservation of energy (potential or kinetic) • momentum • Moments (force x Distance) • Summation of forces	• Showing correct forces on FBD • Sign conventions • Showing correct forces on FBD	• Use of vectors to find moments

Appendix C.2 UTS MRMF Question Analysis Spreadsheet

Knowledge Categories			
	A. Concrete associations	B. Verbal information	C. Fact systems
1. Concrete Facts		• Terminology	• Units • Sign conventions • Determining tension or compression • Equations for calculating second moment of area
	A. Linear Procedures	B. Multiple discriminations	C. Algorithms
2. Procedures	• force components • Calculating second moment of area for complex shape • Determining centroid for complex shape • Summation of forces/moments • calculating stress/strain • Calculating elongation • Integration	• Isolation of members/joints/components (Q1) • Identifying Zero-forces members in trusses • Identifying secions in beams for V & M calculations • Finding eq'n for applied load • Axial Force Diagrams • Shear force Diagrams • Bending moment Diagrams • Use of trigonometry/components in force calculations	• Method of sections • Method of Joints
	A. Concrete concepts	B. Defined concepts	C. Concept systems
3. Concepts		• 2nd moment of area for complex shape (ie. Dist. Form centroid etc.) • Stress/strain & youngs modulus • dM/dx=-V • dV/dx=-w • Distributed loads • Tension/compression	• Free body diagrams • Internal forces - Axial Force • Internal forces - Shear Force • Internal forces - Bending Moment (including Max BM)
	A. Rules of nature	B. Rules of action	C. Rule Systems
4. Principles	• Moments (force x Distance) • Static equillibrium	• Showing correct forces on FBD • Identifying change in I calc between Ixx & Iyy	

Appendix C.3 UTAS MRMF Question Analysis Spreadsheet

Knowledge Categories			
	A. Concrete associations	B. Verbal information	C. Fact systems
1. Concrete Facts		• Terminology	• Units • deg/s to rad/s • Sign conventions • Equations for calculating second moment of area
	A. Linear Procedures	B. Multiple discriminations	C. Algorithms
2. Procedures	• integration (accel/vel/dist) • Calculating second moment of area for complex shape • Centroid of complex shape • friction forces • Normal accelleration • Kinetic energy • Decceleration/consv. Momentum • power • Simultaneous equations • Area of circle	• linear motion (Q4a) • Calculating Reaction Force 5a (summation of forces) • Axial Force Diagrams • Shear force Diagrams • Bending moment Diagrams • Velocity/acceleration vector solution (4b) • Force components	• Equations of curvilinear motion for system
	A. Concrete concepts	B. Defined concepts	C. Concept systems
3. Concepts		• Non-uniform accelleration • Kinetic energy • Conservation of momentum • Unformly distributed loads (and conversion to pt load) • 2nd moment of area for complex shape (ie. Dist. Form centroid etc.) • Static equillibrium • Power • Friction • relative accel.	• Curvilinear motion equations • Free body diagrams • Internal forces - Axial Force • Internal forces - Shear Force • Internal forces - Bending Moment
	A. Rules of nature	B. Rules of action	C. Rule Systems
4. Principles	• Moments (force x Distance)	• Summation of forces • Showing correct forces on FBD • Forces due to cable tension and pulleys	

Appendix C.4 AMC MRMF Question Analysis Spreadsheet

Knowledge Categories			
	A. Concrete associations	B. Verbal information	C. Fact systems
1. Concrete Facts		• Units • Quadratic equation • Newtons laws • Conservation of linear momentum law • Terminology	• Identifying force/momentum components • Sign conventions • Trigonometry rules
	A. Linear Procedures	B. Multiple discriminations	C. Algorithms
2. Procedures	• Calculating kinetic energy • Rotational kinetic energy • Rotational acceleration • Impact restitution • Calculating momentum • Point of force concurrency (graphical) • Force polygon (graphical) • Natural frequency	• Summation of forces • Friction force • Projectile motion • Cable stress & Strain • Eq'n of motion for spring mas damper sys • Central impact analysis	• Force due to thermal exp • Shaft balancing • Graphical analysis of velocity
	A. Concrete concepts	B. Defined concepts	C. Concept systems
3. Concepts		• Stress/strain/elongation • Conservation of momentum • impact restitution • Normal acceleration • Thermal Expansion • Rotational motion/inertia • Torque • mass moment of inertia • angular momentum	• Curvilinear motion • Free body diagrams
	A. Rules of nature	B. Rules of action	C. Rule Systems
4. Principles	• Conservation of Momentum • Conservation of energy • momentum	• Showing correct forces on FBD • Sign conventions • Vector addition (graphical)	

Appendix D Exam Error Summary Spreadsheet Data

Table D.1 UOW exam error data

Problem Area	***Problem Type***			
	A. Factual	**B. Procedural**	**C. Conceptual**	**D. Rule**
1. Vectors	Interpereting vector coordinates*	Calculating unit and position vectors* Applying Vector dot product to find vector translation onto axis*** Applying Vector cross product to find vector translation about a point***	Purpose/use of vector dot and cross products***	
2. Free body diagrams		Isolating free body*	Identifying force couples* Identifying all forces acting**	Determining correct direction of Force vector** direction of Force normal to path***
3. Truss Analysis	Tension and compression**	Method of sections (cutting members)**		
4. Shear and bending moment		Constructing shear force diagram** Constructing bending moment diagram***	Calculating shear forces** Calculating bending moments***	
5. Second moment of area	Units*	Calculating 2nd moment of area for complex shape**	Understanding significance of controid for complex shape**	
6. General	Units** Sign conventions*			
7. Energy		Calculating potential energy (using correct information)***	Conservation of energy***	Kinetic and/or potential energy**

		Calculating Kinetic energy**	
8. Linear Momentum		Calculating Momentum*	Conservation of Momentum**
		Calculating Impulse***	Impulse***
9. Oblique impact		Oblique impact analysis, separating into components for solution***	

* Error made by less than 25% of students

** Error made by more that 25% and less than 50% of students

*** Error made by more than 50% of students

Table D.2 UTS exam error data

	Problem Type			
Problem Area	**A. Factual**	**B. Procedural**	**C. Conceptual**	**D. Rule**
10. Free Body Diagrams		Isolating free body***		Determining correct direction of Force vector***
11. Truss Analysis	Sign converntions/force directions**	Identifying zero force members**		
		Method of sections (cutting members)***		
		Method of Joints***		
12. Force and moment analysis		Finding correct components of forces**		
		Correct summation of Forces/moments**		
13. Second moment of area	Units*	Finding Centroid**		
		Calculating 2nd moment of area for complex shape **		
14. Internal Forces		Axial Force Diagrams**	Finding Axial force*	
		Constructing shear force diagram**	Calculating shear forces*	
		Constructing bending moment diagram**	Calculating bending moments*	
15. Stress and Strain	Correctly interpreting question - no. of strands**	Simple calculations of stress strain*	knowing how to start question*	

* Error made by less than 25% of students

** Error made by more that 25% and less than 50% of students

*** Error made by more than 50% of students

Table D.3 UTAS exam error data

Problem Area	Problem Type: A. Factual	B. Procedural	C. Conceptual	D. Rule
16. Second Moment of Area	Correct use of equations for second moment of area**	Calculating 2nd moment of area for complex shape ***		
		Finding Centroid***		
17. Polar coordinate motion	converting to and using rad/s***	Vector solution***	Relative acceleration***	
		Equations of curvilinear motion using polar coordinates***		
18. Free body diagrams		Isolating free body**	Identifying force couples***	Force direction in cable, Tension only***
19. Force		Force components*	Friction force*	Force directions due to in cables and pulley's***
		Calculating Friction Force**		
		Summation of several forces**		
20. Internal forces		Axial Force Diagrams(mod)	Finding Axial force(mod)	
		Constructing shear force diagram(mod)	Calculating shear forces**	
		Constructing bending moment diagram(maj)	Calculating bending moments**	
21. Linear motion		derivation of accel & vel to distance***	Conservation of momentum**	
		Momentum**	Non-uniform acceleration**	
22. Curvilinear motion		Normal Acceleration**		
23. Energy and Power		Calculating power***	Kinetic energy*	
		Calculating Kinetic energy	Power***	

24. Mathematical operations	Units*** Sign Conventions**	Simultaneous equations*

* Error made by less than 25% of students

** Error made by more that 25% and less than 50% of students

*** Error made by more than 50% of students

Table D.4 AMC exam error data

Problem Area	*Problem Type* A. Factual	B. Procedural	C. Conceptual	D. Rule
25. Free Body diagrams		Isolating free body**	Identifying all forces acting**	
26. Polar Coordinate (motion)		Equations of motion for spring mass damper sys***	Mass moment of inertia**	
27. Rectilinear motion			Conservation of momentum*	
28. Curvilinear motion			Normal Acceleration** Curvilinear motion overall***	
29. Laws of motion	Recitation of Newtons Laws of motion** Recitation of Conservation of momentum law**			
30. Force analysis		Finding correct components of forces * Constructing force polygon** Friction Force*		
31. Mathematical operations	Trigonometry rules** Sign conventions***			
32. Linear Impact analysis		Impact restitution**		
33. Projectile motion		Projectile motion analysis***		
34. Stress/strain		Stress & strain in a cable*** Force Due to thermal expansion*		

35. Rotational motion		Shaft Balancing***	Torque**	
		Rotational Kinetic energy*		
		Rotational acceleration*		
36. Graphical analysis		Finding point of force concurrency graphically**		
		Summation of Forces in dynamics probs***		
		Graphical velocity analysis**		
37. Energy				Conservation of energy**

* Error made by less than 25% of students

** Error made by more that 25% and less than 50% of students

*** Error made by more than 50% of students

Appendix E.1 UOW HREC Approval HE08/240

University of Wollongong

INITIAL APPLICATION APPROVAL
In reply please quote: HE08/240
Further Enquiries Phone: 4221 4457

19 September 2008

Mr T Goldfinch
Faculty of Engineering
University of Wollongong

Dear Mr Goldfinch

Thank you for your response dated 18 September 2008 to the HREC review of the application detailed below. I am pleased to advise that the application has been **approved.**

Ethics Number:	HE08/240
Project Title:	A multi-institution approach to predicting and addressing student performance in fundamental engineering mechanics
Researchers:	Mr Thomas Goldfinch, Professor Timothy McCarthy, Dr Anna Carew, Dr Giles Thomas, Ms Anne Gardner, Dr Alan Henderson
Approval Date:	18 September 2008
Expiry Date:	17 September 2009

The University of Wollongong/SESIAHS Humanities, Social Science and Behavioural HREC is constituted and functions in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.* The HREC has reviewed the research proposal for compliance with the *National Statement* and approval of this project is conditional upon your continuing compliance with this document. As evidence of continuing compliance, the Human Research Ethics Committee requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforseen events that might affect continued ethical acceptability of the project.

You are also required to complete monitoring reports annually and at the end of your project. These reports are sent out approximately 6 weeks prior to the date your ethics approval expires. The reports must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

Yours sincerely

P.A. Potter

PP A/Professor Steven Roodenrys
Chair, Human Research Ethics Committee

cc Professor T McCarthy, Civil Mining and Environmental Engineering

Research Services Office University of Wollongong NSW 2522 Australia
Telephone: +61 2 4221 3386 **Facsimile:** +61 2 4221 4338
research_services@uow.edu.au www.uow.edu.au/research
CRICOS Provider No: 00102E

Appendix E.2 UOW HE08/240 Participant Information Sheet and Consent Form (Staff Participants)

University of Wollongong

Participant Information Sheet

Mechanics Educator Interviews

Interviewer
Mr. Tom Goldfinch
Faculty of Engineering
Ph: 4221 3138
Location: 4.G35
Email: tomgold@uow.edu.au

Supervisor
Prof. Timothy McCarthy
Faculty of Engineering
Ph: 4221 35491
Location: 4.G41
Email: timmc@uow.edu.au

Research Purpose and Aims
The purpose of the Mechanics Educator interviews is to hear directly from educators, what factors impact on learning of Statics and Dynamics. We would like to understand why mechanics education is such a challenging subject area for students from the educators' perspective, and hopefully, identify areas of consensus.

Participant Contribution Information
To explore the academics' perspective on engineering mechanics, I request your participation in a short interview of around 30 minutes either face-to-face, or over the phone. Please note that participation is voluntary.

- Information obtained from the Interview will be used as research for a project exploring learning in Statics and Dynamics and may be published as part of this.
- The interview will be recorded on audiotape for later reference by the interviewer only.
- You are free to abstain from any questions.
- The interview will be considered anonymous and your name will not be published, or included in any documentation used outside the interview itself.
- Colleagues will not have access to the interview audio recording, and will not be able to identify you from any of the subsequent documentation.
- Follow up correspondence with the interviewer is welcomed.
- Information, comments and quotes transcribed will be considered publicly available after being de-identified by the interviewer.
- The interview notes and quotes will be subject to your approval, you are free to withdraw your participation prior to this.
- Interview documentation and audio recordings will be stored securely according to university policy.

I would very much like to hear your opinions on introductory mechanics education in the interests of supporting mechanics educational development in the future. I am also happy to discuss the research after the interview.

If you have any questions regarding this research please contact Tom Goldfinch (contact details above). Any concerns or complaints regarding this research should be directed to the University of Wollongong Ethics Officer on (02) 4221 4457.

Faculty of Engineering

Contribution Approval Form

Interview Notes

Insert notes here…

I have read the above notes taken from the interview conducted on ___/___/___ and agree that they are a true and accurate record of the interview Yes/No

I understand that the above notes from this interview will be considered anonymous for the purposes of publication Yes/No

I agree to allow any part of these notes to be used for the purpose of educational research, and associated publications Yes/No

____
Interviewee's name

________________________________ ___/___/___
Interviewee's signature Date

________________________________ ___/___/___
Interviewer's signature (Thomas Goldfinch) Date

Appendix E.3 UOW HE08/240 Participant Information Sheet and Consent Form (Student Participants)

University of Wollongong

Participant Information Sheet

ENGG152 Student Interviews

Interviewer
Tom Goldfinch
Faculty of Engineering
Ph: 4221 3138
Location: 4.G35
Email: tlg70@uow.edu.au

Research Purpose and Aims
The purpose of the ENGG152 student interviews is to hear directly from students, what factors impact on learning of Statics and Dynamics. We would like to understand from the students' perspective, what could be making ENGG152 so difficult, and hopefully, help other students in the future.

Participant Contribution Information
To explore the students' perspective on ENGG152, I request your participation in a short interview of around 30 minutes. Please note that participation is voluntary.

- Information obtained from the Interview will be used as research for a project exploring learning in Statics and Dynamics.
- The interview will be recorded on audiotape for later reference by the interviewer only.
- You are free to abstain from any questions.
- The interviewer may be aware of your final mark range (ie. Pass or fail).
- You are free to withdraw consent at any time prior to the conclusion of the interview.
- The interview will be considered anonymous and your name will not be published, or included in any documentation used outside the interview itself.
- ENGG152 lecturers and tutors will not have access to the interview audio recording, and will not be able to identify you from any of the subsequent documentation.
- Follow up correspondence with the interviewer is welcomed.
- Information, comments and quotes transcribed will be considered publicly available after being de-identified by the interviewer.
- Interview documentation and audio recordings will be stored securely according to university policy.

Your participation in this interview is an opportunity have your say, and voice your opinions on introductory mechanics education at UOW.

If you have any questions regarding this research please contact Tom Goldfinch (contact details above). Any concerns or complaints regarding this research should be directed to the University of Wollongong Ethics Officer on (02) 4221 4457.

Faculty of Engineering

Contribution Approval Form

I have read and understand the above information regarding my contribution in the interview Yes/No

I understand that notes taken during the interview conducted on ___/___/___ will be considered anonymous for the purposes of publication Yes/No

I agree to allow any part of these notes to be used for the purpose of educational research, and associated publications Yes/No

____
Interviewee's name

_________________________________ ___/___/___
Interviewee's signature Date

_________________________________ ___/___/___
Interviewer's signature (Thomas Goldfinch) Date

Appendix F.1 UOW HREC Approval HE10/318

University of Wollongong

INITIAL APPLICATION APPROVAL
In reply please quote: HE10/318
Further Enquiries Phone: 4221 4457

20 September 2010

Mr Thomas Goldfinch
Building 8, Office G13
University of Wollongong
NSW 2522

Dear Mr Goldfinch,

Thank you for your response dated 10 September 2010 to the HREC review letter dated 6 September 2010 of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number:	HE10/318
Project Title:	Investigating students use of online learning resources in engineering mechanics.
Researchers:	Mr Thomas Goldfinch, Prof Timothy McCarthy
Approval Date:	16 September 2010
Expiry Date:	15 September 2011

The University of Wollongong/SESIAHS Humanities, Social Science and Behavioural HREC is constituted and functions in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.* The HREC has reviewed the research proposal for compliance with the *National Statement* and approval of this project is conditional upon your continuing compliance with this document. As evidence of continuing compliance, the Human Research Ethics Committee requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforseen events that might affect continued ethical acceptability of the project.

You are also required to complete monitoring reports annually and at the end of your project. These reports are sent out approximately 6 weeks prior to the date your ethics approval expires. The reports must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

Yours sincerely

A/Professor Steven Roodenrys
Chair, Human Research Ethics Committee

Research Services Office University of Wollongong NSW 2522 Australia
Telephone: +61 2 4221 3386 **Facsimile:** +61 2 4221 4338
research_services@uow.edu.au www.uow.edu.au/research
CRICOS Provider No: 00102E

Appendix F.2 UOW HE10/318 Participant Information Sheet

University of Wollongong

Participant Information Sheet

Learnmechanics.org study session

Facilitator
Mr. Tom Goldfinch
Faculty of Engineering
Ph: 4221 3138
Email: tomgold@uow.edu.au

Supervisor
Prof. Tim McCarthy
Faculty of Engineering
Ph: 4221 4591
Email: timmc@uow.edu.au

Purpose of the Research

The purpose of the Learnmechanics.org study session is to hear directly from students how the learnmechanics.org website might be useful for independent study. We would like to gather information on how student make use of the site, and whether or not it can help to improve learning in ENGG152.

Method and Demands on Participants

To gather this information, the researchers would like to ask you how you are going in ENGG152, and what topics you find easy or difficult. After this, we would like to introduce the learnmechanics.org site. You will be given a number of sample problems to choose from and work through, and access to a wide range of online learning resources through learnmechanics.org. While doing this, you will be asked to think aloud, commenting on the usefulness of online resources, and stating any questions you may have. This session will be video recorded, and will take around 45 minutes (or longer if you wish). After the session, with your permission, we would also like to obtain your quiz marks for ENGG152. These marks will provide us with a greater understanding of how your performance in the subject relates to the learning resources you found most useful.

Possible Risks and Inconveniences

The time taken by this study session will be around 45 minutes, however, if you are finding it useful we are happy for it to run longer. The video recording and quiz marks will only be reviewed by the facilitator, Tom Goldfinch. After analysis has been completed recordings will be kept in secure storage, and you will not be identifiable from any published research data. The facilitator is not involved with assessment or running of ENGG152, and any statements you make will only be relayed back to lecturers or tutors of the subject on an anonymous basis. You are also welcome to contact the facilitator with any follow up questions after the study session.

Funding and Benefits of the Research

This study is funded by the Australian Learning and Teaching Council. The data collected in these study sessions will be used to evaluate the viability of the learnmechanics.org site as a useful learning tool in engineering mechanics. After the session, you are also welcome to continue using learnmechanics.org for your own study purposes.

Ethics Review and Complaints

This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. If you have any concerns or complaints regarding the way this research has been conducted, you can contact the UoW Ethics Officer on (02) 4221 4457.

Faculty of Engineering

Appendix F.3 UOW HE10/318 Consent Form

University of Wollongong

Participant Consent Form

Learnmechanics.org study session

Facilitator
Mr. Tom Goldfinch
Faculty of Engineering
Ph: 4221 3138
Email: tomgold@uow.edu.au

Supervisor
Prof. Tim McCarthy
Faculty of Engineering
Ph: 4221 4591
Email: timmc@uow.edu.au

I have been given information about the learnmechanics.org study session and discussed the research project with Mr. Tom Goldfinch who is conducting this research as part of an Australian Learning and Teaching Council funded project.

I have been advised of the potential risks and burdens associated with this research, and have had an opportunity to ask Mr. Tom Goldfinch any questions I may have about the research and my participation.

I understand that my participation in this research is voluntary, I am free to refuse to participate and I am free to withdraw from the research at any time during the study session. My refusal to participate or withdrawal of consent will not affect my relationship with the University of Wollongong or university staff, including the researchers.

If I have any enquiries about the research, I can contact Mr. Tom Goldfinch on the contact details at the top of this page, or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on 4221 4457.

By signing below I am indicating my consent to:

- Participate in a video recorded study session focusing on online engineering mechanics learning resources.
- Allow my quiz marks in ENGG152 to be used in the research.
- Allow material gained from the interview to be used in publications, on the condition that I will not be identifiable from any published material.

I understand that the data collected from my participation will be used for engineering education research and publications, and I consent for it to be used in that manner.

Signed ....

Date ..../....../......

Name (please print)

....

Faculty of Engineering