THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

Faculty of Engineering, Computing and Mathematics

Asking Genius Friend Worked:

Students' Experiences of Threshold Concepts

Semester 2 - 2012

ENSC 1002 Material Behaviour from Atoms to Bridges

ENSC 2001 Motion

ENSC 2002 Energy

THE UNIVERSITY OF WESTERN AUSTRALIA
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Executive Summary

The aim of this research was to investigate how students experienced the threshold concepts of three engineering foundation units within the developed pedagogy. Student experiences were noted during class observations, captured in a survey and revealed more intensely in interviews of students studying the three engineering foundation units Materials, Motion, and Energy during Semester 2, 2012.

When encountering a threshold concept, students adopted three strategies: asking, doing and gathering. ‘Asking’ included asking students, the lecturer, a parent, the tutor, a genius friend, their group, older students, as well as explaining it to another student when he or she asks for help. ‘Doing’ encompassed working through examples and checking the solutions, practice, and repetition. ‘Gathering’ reflected more passive activities such as watching YouTube lectures and explanations, rewatching lectures, reading through the lecture notes, reading a text book, reading the notes or text books of a more senior student or someone who had already completed the unit, watching someone else explaining the concept or working through a question. ‘Gathering’ involved accumulating enough *explanations* from different sources and at different levels of detail, or enough examples until it all fell into place. Most students used a combination of the three strategies.

When ‘asking’ someone to help them learn a threshold concept, a hierarchy emerged, The most common person to ask was a peer, and in particular, a “genius friend”, someone who knew the concept and was safe to ask. Less commonly, the facilitator was approached. Finally, the lecturer was rarely asked.

Most students stated they did not find most of the threshold concepts difficult. After asking, doing and gathering, students felt they understood a concept and it was no longer seen as difficult.

Students expressed reluctance to engage with pre-reading. This highlighted a lack of appropriate reading skills in the students, which required the ability to read a large amount of information, distil the essential messages, summarise those messages, and incorporate those messages into a mental schema of the area being learnt.

Finally, international students were reluctant to comment negatively on any aspect of their learning experiences.

Recommendations: Visualisations

- *Build a bank of explanations that students have found useful (e.g., Khan Academy)*
- *Facilitators and lecturers to find visualisations for concepts that students find difficult.*

Recommendations: Doing

- *Build a bank of questions with solutions, or sources of questions.*
- *Encourage students to recognise that even through they have answered a question ‘correctly’, that does not mean that they understand the underlying concepts.*
- *Find other ways for students to apply their understanding of a concept beyond just the correct answer to a question.*

Recommendation: Reading

- *Provide explicit training in how to read and process large amount of written materials*
- *Highlight to students that large amounts of technical reading and ‘self-learning’ is still part of engineering practice, regardless of preferred learning style.*

Recommendations: Asking

- *Recognise the asking hierarchy (lecturer (least likely) – facilitator (sometimes) - genius friend (most likely)):*

Lecturers and Unit Coordinators:

- *When a student does ask for assistance, recognise this as a rare learning opportunity. They have most likely exhausted other avenues.*
- *Reconsider the practice of 'Consultation Hours'. If the lecturer is the helper of last resort, then offer the help when required. Perhaps Consultation Hours could be replaced with appointments made by email.*
- *Don't be surprised to have to go back to basic principles. Try to understand the question from the student's viewpoint.*

Facilitators:

- *When a student does ask for assistance, he or she is approaching you after having already tried other approaches.*
- *Don't be surprised to have to go back to basic principles. Try to understand the question from the student's viewpoint.*
- *Find ways to help the student visualise abstract concepts. Use metaphors to allow students to draw connections with real life examples.*
- *If students are chatting in a class, more likely than not they are discussing their work.*
- *Sometimes is a student is struggling with a concept, the class is as well. Be prepared to call the class to silence to offer an explanation or your working out to the whole class.*

Recommendation: International

- *Recognise the vulnerability some international students may experience.*
- *Take the effort to introduce technical and unfamiliar terminology.*

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Terminology & Abbreviations

Class	A term used in this report to cover both Information Sessions and tutorials.
Energy	Short name for the unit ENSC 2002 Energy
ENSC	Engineering Science. Used to code units.
Facilitator	A facilitator is hired by the university to deliver the IS's lessons plan, mark work. Sometimes called a *tutor* by the students.
Foundation Units	A set of four units that are required to be completed by all engineering students.
IS	Information Session - a 2 hour, interactive session where students work in groups to complete required tasks and answer problems and questions. Each group contains no more than 6 students; each IS contains no more than 5 groups. Students sometimes call these Information Sessions 'tutorials'. Each IS is led by a facilitator. In this report, the term *class* refers to IS / tutorials.
Materials	Short name for the unit ENSC 1002 Material Behaviour from Atoms to Bridges
Motion	Short name for the unit ENSC 2001 Motion
TC	Threshold Concept
Unit	A 13 week set of learning activities, prepared by the university. 4 units a semester is considered a typical full time load.
UWA	University of Western Australia

1 Introduction

One curriculum design tool involves threshold concepts, those concepts that students find troublesome, are critical to students' progress and are transformative for students (Meyer & Land, 2003). In designing curriculum around threshold concepts, less time and effort is allocated to concepts that students find easy to acquire, or are able to acquire themselves from resources such as text books, videos and study guides, and more time and effort by teaching staff is allocated to difficult concepts such as threshold concepts. In this research, three engineering units that had been designed around threshold concepts were studied. In particular, this research focused on how students experienced each unit's threshold concepts within the developed pedagogy of student-centred group learning.

2 Context

The Engineering Curriculum at the University of Western Australia (UWA) has been extensively redesigned. In particular, the units at the beginning of engineering studies that provide content and skills common to all engineering disciples - 'The Foundation Core Engineering Units' - use different scopes of content, teaching methods and learning spaces (Male & Baillie, 2011a). One aspect of the curriculum redesign involves using threshold concept theory to help determine which content should be included (Male, MacNish, & Baillie, 2012). Threshold concepts are those concepts that students find troublesome, are critical to students' progress and are transformative for students (Meyer & Land, 2003). An extensive process of consultation with UWA staff and students led to a set of threshold concepts (Male & Baillie, 2011b). These threshold concepts were grouped around four key themes – global challenges, materials, energy and motion. These four key themes became the four Foundation Core Engineering Units.

Further, the teaching methods were also altered. The four foundation core engineering units were structured around two interactive two hour sessions each week, with students working cooperatively and interactively in groups of around six. The maximum number of groups in one room was five.

Following on from the identification of threshold concepts, the aim of this research was to investigate how students experienced the identified threshold concepts within the developed pedagogy. The investigation considered three of the four foundation core engineering units – Materials, Motion, and Energy - during Semester 2, 2012. This was the second time these units had been offered.

This research was *not* about students' experiences of the redesigned engineering foundation units. Students did provide such feedback during the survey, but this feedback fell outside the scope of this study's research question, which focused on threshold concepts.

3 Research Scope and Procedures

Research into student experiences requires the student to share his or her inner life. Such sharing can be personal, through talking with a researcher, or impersonal, through comments on a questionnaire. Both methods were used in this research.

3.1 Research Process

To understand the complexities of how engineering students experience threshold concepts, an interpretivist approach that recognises and values the students' myriad realities is warranted. Phenomenology, a theoretical perspective that seeks to provide a description of the key aspects of a lived experience, provides an apt framework for the research. A basic interpretive methodology (Merriam 2002) allows an understanding of how students make sense of their lived experiences, without necessarily developing a theory or identifying the essence of a phenomenon. The methods for collecting the data began with observations, evolved to include a questionnaire and ended with interviews to explore observation and questionnaire data in greater detail. Although this research was planned on a phenomenological approach, ultimately, to answer the research question, the research followed an explanatory sequential mixed methods design (Creswell, 2012).

Ethics approval for research with human subjects was sought and approval granted, with the research process taking place at arms length to the teaching staff in the Engineering Foundation Teaching team. The Chief Investigator, Professor James Trevelyan, forms part of the School of Mechanical and Chemical Engineering, and the researcher, Jolanta Szymakowski, is an independent researcher and was employed for the project. The Human Research Ethics Approval Letter forms Appendix 1.

3.1.1 Qualitative Data

The qualitative data was acquired though observations and interviews. Twenty five (25) interactive two hour sessions were observed (9 Motion, 11 Energy and 5 Materials). Nine interviews with groups of 2 to 5 students were conducted, comprising 28 students (3 female, 25 male).

Observations of the interactive two hour sessions were with the permission of the sessions' facilitators. The researcher employed direct observation, making unstructured notes and asking students an occasional clarifying question. As much as possible, the same two hour interactive sessions each week were observed, allowing students to become familiar with the presence of the researcher.

The group interviews used a semi-structured format, where an interview protocol formed the starting point for the interview without constraining student responses. This allowed unanticipated material to emerge and for the interviewee to shape the interview.

The interview protocol explored how a mind map of the unit matched students' experiences of the unit; what the students spent most of their time on during the unit; which threshold concepts students found tricky / easy / tested badly on; what really worked for them to learn a threshold concept; and what led up to the moment when a threshold concept 'clicked' for them. A copy of the interview protocol is in Appendix 2.

All students agreed to be recorded. Notes were also taken during the interviews. Interviews were uploaded, transcribed, coded and themed in NVivo 10.

A second source of qualitative data emerged during the study. After 4 weeks of observations, little evidence of grappling with threshold concepts was seen during the two hour interactive sessions, and it was realised a way of capturing student activity outside the two hour interactive sessions was required. A short questionnaire, slightly modified for each unit to include each unit's threshold concepts, was developed, printed and with the permission of each unit coordinator, given to each Motion, Energy and Materials student during a two hour interactive session. A copy of each questionnaire forms Appendices 3, 4 and 5. The completed questionnaires were transcribed into an Excel spreadsheet, and uploaded into SPSS and Qualtrics. Student's comments in the three open-ended questions provided another rich source of qualitative data.

3.1.2 Quantitative Data – The Questionnaire

As stated in §3.1.1, a way of capturing student activity outside the two hour interactive sessions was required and a short questionnaire was developed. A copy of each questionnaire forms Appendices 3, 4 and 5. The completed questionnaires were transcribed into an Excel spreadsheet, and uploaded into SPSS and Qualtrics.

The questionnaire was structured into 5 parts. The parts, and the number and type of items in each part, are described in Table 3.1 and below.

Table 3.1 Structure of the Questionnaire

Part	Title of the Part	Number and type of items in the Part
Part A	About You and Your Study	6 demographic items
Part B	Your Preparation for the Engineering Foundation Classes	1 sliding scale item; 2 descriptive multiple choice items; 1 open ended question.
Part C	In Class and After	1 5 point Likert scale question; 1 sliding scale item.
Part D	Your Experiences of Learning Threshold Concepts and Understandings	Up to 9 questions, each question consisting of 3 Likert continuous scale questions
Part E	Final Comments	1 open ended question

Part A, About You and Your Study, consisted of 6 demographic items. These included the student's gender, whether this was the student's first year at university, and the state/country where secondary school was completed. Other items asked whether more than one ENSC unit was being studied during the Semester, which ENSC units had previously been completed, and the student's other field of study or major.

Gender was included so that the perception of female engineering students, a cultural minority in this context, could be identified. Whether this was a student's first year at university was included so that the views of those students new to university studies could be separated from those already with experience of tertiary teaching or the way related units had been presented in the past. The state or country where the student had completed secondary schooling was included to allow a comparison between the responses of international and local students. Whether the student was studying another ENSC unit simultaneously was included to see if there were commonalities across both units. Whether the student had previously completed an ENSC unit was included so that, together with the previous item, the responses of those completely new to ENSC units could be compared to those for whom this was their first experience of ENSC units. The student's other field of study was required to see if particular responses were clustered around particular fields of study.

Part B, Your Preparation for the Engineering Foundation Classes, consisted of 4 items and sought to identify the specific activities undertaken by students in preparation for their interactive 2 hour session. The first item asked about how many hours a week was typically spent preparing for an Information Session (IS) (the interactive 2 hour session). The second question asked students to select from a list of 7 options the types of activities undertaken in preparation for the IS (e.g., "Accessed LMS"). The list ended with an open category of "Other". The third question asked students if something wasn't clear to them this week, what it was, and asked students to select from a list of 13 options the types of activities undertaken to help their understanding (e.g., "Found a video on YouTube"). The list ended with an open category of "Other". The final item in Part B then invited student to an open ended response: "*Reflecting* on what you did to learn an unclear topic, what did you find worked very well for you? What did not work?"

Part C, In Class and After, consisted of two items. The first item asked about the importance of various aspects around learning in class (e.g., "When thinking about your learning in class, how important is – working with group members?"), using five-point Likert scales. Six aspects were listed, as well as "Other". The second item asked how many hours a week after the class was typically spent consolidating knowledge and completing homework.

Part D, Your Experience of Learning Threshold Concepts and Understandings, presented the unit specific threshold concepts explored thus far in the unit as well as the four common engineering threshold concepts and sought how the students felt about each concept. Students were asked for a rating around the unit specific threshold concepts on a continuous Likert scale against three statements: how hard was the concept (Really hard to not hard at all); Was enough time allocated in this unit to enable you to learn this concept (Need more time to Prefer less time); and How confident do you feel about *applying* this concept to the material covered so far in this unit? (Very confident to Not confident at all).

Students were asked to rate the four common engineering threshold concepts rating on a continuous Likert scale also against three statements. Using communication as an example, the three statements were: How **important** do you believe *communication* is to successful engineering practice? (Very important to not at all important); Since the start of this unit, I have gained a greater **ability** to *communicate* (Strongly agree to strongly disagree); and How confident do you feel about your abilities to be an **effective** *communicator?* (Very confident to not confident at all).

The final section of the questionnaire, Part E Final Comments, offered around a third of a page for open ended comments, suggestions and feedback.

Draft questionnaires were given to the unit coordinators in the three ENSC units Materials, Energy and Motion, the Chief Investigator and the developer of the ENSC threshold concepts, Dr Sally Male. The questionnaire was modified in response to their feedback. The questionnaire was field tested with three students in the ENSC Materials unit. The field test results showed the survey to be clear and easy to complete, taking less than 5 minutes to complete.

3.1.2.1 Data Collection

Data Collection began in the first week of September 2012, week 6 of a 13 week semester and was completed a week later. The questionnaire and a one page set of notes for the facilitator were sent to the administrative staff for the ENSC units. The administrative staff photocopied the questionnaires and notes ready for the facilitators to collect. The facilitators then distributed the paper questionnaire to all the students in their IS and collected the completed questionnaires, which were returned to the administrative staff. The researcher then collected the completed surveys.

All students in the three ENSC units (*n* = 737) were invited to complete the questionnaire.

3.1.2.2 Data Analysis and Interpretation

By the end of week 7 of semester, 576 useable questionnaires had been returned, representing a 78% response rate. The numbers of Information Sessions, enrolled students, useable surveys and response rate for each unit is shown in Table 3.2.

Table 3.2 Numbers of Information Sessions, enrolled students, useable surveys and response rate per unit.

	ENSC 1002 Materials	ENSC 2001 Motion	ENSC 2002 Energy
No of IS	19	6	6
No of students enrolled	419	155	163
No of usable surveys	358	125	93
% response rate	85%	81%	57%

An additional 27 Energy questionnaires were submitted to the researcher around three weeks after preliminary data analysis had been completed and reported to the unit coordinators. Had these questionnaires been included, Energy would have achieved a 74% response rate.

A descriptive research methodology underpinned the survey analysis. Summary statistics of the data was produced. The data was also separated into two using the demographic features – gender, whether the student was in the first year of higher education, whether the student had completed an engineering foundation unit, whether the student attended a local high school – and the responses of each group compared.

3.1.2.2.1 Qualitative Data Analysis and Interpretation

The questionnaire included three open-ended essay questions, two in Part B and one in Part E. There were responses from 368 and 196 respondents to the two open-ended questions in Part B, Your Preparation for the Engineering Foundation Classes. The final open-ended question in, Part E, Final Comments, attracted 216 responses. A summary of the total number of responses to the three open-ended questions is shown in Table 3.3. Around two thirds of the survey respondents in each unit (63%, 61%, 71%) or around half the enrolled students in the units (54%, 48% 40%) chose to write what worked for them to learn an unclear topic. This high response rate leads to optimism in the validity of subsequent analysis of these comments.

Between half and two thirds of the survey respondents chose to write additional comments in Part E, Final Comments. Some of these comments included feedback, suggestions and observations about the unit in general. These comments were outside the scope of this study, which is students' experiences of threshold concepts. Nonetheless, these comments are listed in Appendix 9.

Because of the manageable number of responses for Part B and Part E, these were coded and analysed by hand using a process described in Creswell (2012) and Saldaña (2013). Responses were divided into segments of information, labelled into codes, and collapsed into themes.

Table 3.3 Number of comments in the three open-ended questions in each unit

	ENSC 1002 Materials	ENSC 2001 Motion	ENSC 2002 Energy	total
B4. *Reflecting* on what you did to learn an unclear topic, what did you find worked very well for you?	226	76	66	368
B4 b. What did not work?	131	41	24	196
E. Final Comments	124	40	52	216
No of students enrolled	*419*	*155*	*163*	
% of enrolled students who wrote what worked for them to learn an unclear topic	*54%*	*48%*	*40%*	
No of useable surveys	*358*	*125*	*93*	
% of useable survey respondents who wrote what worked for them to learn an unclear topic	*63%*	*61%*	*71%*	

3.1.3 Ethics

Ethics approval for this study (RA/4/1/5500) was granted from 16 July 2012 to 01 July 2013, in accordance with the National Statement of Ethical Conduct in Research (Australian Government, 2007), and the policies and procedures of The University of Western Australia. Confidentiality and anonymity was assured through a hands-off process of survey distribution: the questionnaire was photocopied by administrative staff and distributed by the facilitator. Survey respondents were not required to identify themselves.

The questionnaire included a general introduction assuring participants that the survey was anonymous, voluntary and all information would remain confidential. No separate Participant Consent Form was required, as completion of an anonymous questionnaire is considered evidence of consent to participate in the study (Australian Government, 2007).

A copy of the Human Research Ethics Approval Letter forms Appendix 1.

4 Findings

The aim of this research was to investigate how students experienced threshold concepts in three engineering foundation units within the developed pedagogy. Student experiences were captured through observation in classes, self-reports on a questionnaire and in interviews. This chapter reports the findings of the observations, the survey and the interviews.

4.1 Observed Data

Twenty five (25) interactive two hour sessions were observed (9 Motion, 11 Energy and 5 Materials). As much as possible, the same two hour interactive sessions (IS) each week were observed, allowing students to become familiar with the presence of the researcher. Motion and Energy Information Sessions were observed from Week 2 until Week 11 of Semester; the Materials Information Sessions were observed during Weeks 10 and 11.

Note that student comments about their interactive two hour sessions and the unit in general are listed in Appendix 8.

4.1.1 Motion IS

The Motion Information Sessions were all held in Room 2.61, a typical classroom on the second floor of a 1950s style building. A wall length whiteboard filled the front of the room and another the back of the room; to the left was a wall of windows that looked onto a wall. Also at the front was a lectern and table. There were two movable whiteboards at the right.

The rest of the room contained six groups of six tables and chairs. As the room was wider than it was longer, the long axis of the groups of tables ran parallel to the front of the room, and there were three rows of tables. Student sat at five of the groups of tables, leaving the group of tables in front of the lectern vacant.

The lesson plan for each Information Session began with a quiz on the background readings. After a few weeks, students knew the drill. A discussion on the quiz answers immediately followed. One facilitator asked each group to present their quiz solutions, another facilitator just talked through the solutions on the board. The facilitators also asked the students questions about their solutions, the assumptions that had been made, their understanding of conventions.

After the quiz were the homework questions. Students were required to access the learning management system, download and read the current's weeks readings and answer the posted questions before the Information Session. One facilitator asked each group to present their homework solutions on the whiteboard nearest their group, and the other groups compared and contrasted their answers. In another IS, the facilitator simply wrote the solutions on the board, talking his way through his steps. Students murmured and talked with each other as the facilitator explained his steps – they were talking because they didn't understand and were explaining it to each other. Again, the facilitators asked the students questions about their solutions, the assumptions that were made, their understanding of conventions, highlighting differences in their approaches, and clarifying the required approach.

A problem set was then given to each student. The facilitators directed the students to complete the first question, setting a time limit. Each group wrote their solution on the whiteboard, and explained their approach. The same pattern was followed for the remaining questions.

At the break halfway through the two hour session, a female student told me that the examples (questions) were easy, and she could do them intuitively. However, she noted that the focus was not the questions themselves but reinforcing the problem-solving heuristic. She wanted more complicated problems. In another part of the room, a group of students was having problems understanding a concept, so during the break they asked the tutor, and kept discussing amongst themselves.

Most of the students in the classes were male. In one IS, there were five groups of students: two groups of five males, two groups of three males and one female, and one group of two males and three females. Some groups worked as individuals – each member of the group attempted the problem set by themselves. When a student asked for help, it was readily given. The unit content was electrical theory, and the following student comments were heard: “The ones I hate most are when you have to rearrange it” “You’ve done GENG1002? How do you …” How can you tell what is in series and in parallel? I thought I knew but I just can’t see it in the circuit” “I did Energy last Semester but it didn’t help!”.

The students talked amongst themselves - using the language of the discipline, not paraphrasing.

Two days later was the scheduled workshop (“practical”) for this IS. Each group was split in half, forming subgroups of two or three. Each subgroup worked with their partner subgroup, but there was a lot of walking around, looking at other students’ work as well. “Did they ground it?” “Where is 1 in the chip?” “Did you do Energy last Semester?” “I did Energy last Semester”. More senior students were talking with newer students and gave them advice, asking what units they are studying. Newer students asked more senior students about the units they studied, and the projects they have worked on. There was a sense of genuine camaraderie.

4.1.2 Energy IS

The Energy Information Sessions were all held in Room ESE 2.03, a lab room rather than a classroom. A portable whiteboard was located at the front of the room and a small whiteboard at the back of the room; to the left was a wall of angled windows providing light but no view. At the front was a bench with lab equipment, a portable screen and the portable whiteboard.

Instead of tables and chairs, the furniture in this lab room consisted of lab benches and stools. There were three benches - two at the front, and one at the rear. A locked small equipment room occupied the space where the fourth bench would have been.

In the middle of each bench was a raised island supporting two sets of digital oscilloscope, function generator, digital multimeter and power supply. The raised island split the bench into two – facing front and facing rear. Both sides of the bench also contained a PC, and each bench was long enough to accommodate 6 stools.

The lesson plan was projected onto the portable screen at the front. After the opening quiz, students started work on the problem sets. Students worked mostly individually, since the bench seating didn’t easily facilitate discussion. Students at the back benches struggled to see over the island equipment to the facilitator’s explanations on the front whiteboard. Others used their smartphones to photograph the displayed solution. Students who had raised their hands to seek help from the facilitator turned to Facebook, checked their emails or discussed their weekends while waiting.

Each group was required to wire up a given circuit on breadboard. Only three people in each group could see or touch the breadboard, so the other group members returned to revising the on-line lecture notes, attempting other problems or Facebook.

Some of the students were familiar – they also formed part of the Motion ISs that I observed.

Presentation time – groups presented their research on a given topic. Most only read from their smartphones / tablet. I turned on my smartphone, Googled the topic, and followed the students as they read word for word from Wikipedia. Only one group prepared a PowerPoint presentation.

In another IS, a facilitator invited those students who had difficulty with Question 1 to leave their places and to gather at the whiteboard. He directed the other students to just pipe down a bit. Two students drew their solutions on the whiteboard, each explaining the process they followed. The facilitator picked up a lack of understanding of the term ‘datum’, and explained the function of a datum in circuit analysis. The same process was followed for Question 2. This time the facilitator asked if anyone used a different method to solve the problem. When there is no answer, he demonstrated an alterative method. The students returned to their stools where they continue to discuss as they work through the remaining problems.

Other students were struggling with phasor analysis and opened up Wikipedia, discussed the lecture notes, or watch YouTube videos on the topic. Some just worked solo with the laptops "I'm fine working this way".

There was an air of resignation over the class.

4.1.3 Materials Tutorials (IS)

The Materials Tutorials or Information Sessions were all held in the newly refurbished engineering learning centre. New chairs, tables, carpet, whiteboards. Each room occupied a corner of the first floor of the building, with windows looking externally on two sides and windows looking internally on a third side. The fourth wall was a whiteboard wall; the external windows could be partially blocked by sliding whiteboards on tracks. There was no clear front, and no front table. Portable, foldable tables were stacked to one side. Six large tables were arranged in a star pattern around the room. Each table was large enough to accommodate six chairs and thus six people.

A trio of students was at a whiteboard going through one problem (an exam question) that one student did not understand. One was explaining, a second asked a question at each step of the explanation, and the third chipped in occasionally with an alternative viewpoint or a question of his own.

The facilitator was working one on one with a female student. Step by step she explained the process, back to the basics. "But I don't understand how …." "I understand [this], but I don't understand [that].."

In another IS, the students were working through their problem set. Hands were up waiting for the facilitator. While waiting, students checked their smartphones and laptops. Others just chatted about the upcoming holidays and their enrolments for next year. Some were working their way through the online lecture notes: "He just went straight into it, he never said what it was ('cold-worked')". Yet others asked the facilitators for more practice questions or previous exam questions "The more you do, the less stress you have".

A student asked me how my research was going, about how students learn tricky concepts. I responded "Slowly". He looked around at the class: **"They're all discussing. That's how they learn".** [emphasis added].

4.2 Survey Data - Quantitative

After four weeks of observing students in classes and seeing little evidence of grappling with threshold concepts, it was surmised that students might be undertaking the bulk of their grappling *outside* their classes – before and after. A survey was thus proposed, and a questionnaire developed with questions that aimed to capture not just student activity outside their classes, but their perceptions of the unit's threshold concepts and an invitation to reflect on what works and what doesn't work for their learning.

Student activities observed in the classes (e.g., talking with group members, YouTube, asking friends) informed the questions developed for the questionnaire.

All students studying three of the Engineering Foundation Units – Materials, Motion and Energy (n = 737) were invited to participate in this survey by completing a paper questionnaire during class. A survey response rate of 78% was achieved. This consisted of 576 useable surveys.

The survey results are presented by questionnaire part first, and then by unit.

4.2.1 Part A: About You and Your Study

Part A of the questionnaire sought to identify some of the key demographic features of the survey respondents. This section of the results summarises the demographic data based on gender, whether the students is in their first year of higher education, location of high school, whether the student has already completed an ENSC unit, and whether the student is studying another ENSC unit at the same time.

4.2.1.1 Materials

Figure 4.1 presents some of the key demographic features of the survey respondents in the Materials unit. Of the 358 completed surveys, 76 (21%) were female, and 280 (79%) were male. Two hundred and twenty nine students (65%) were in their first year of higher education, with the remaining 125 (35%) in their second year or later. Some students reported being in their final year of engineering studies. Such a diverse spread of previous higher education experience is to be expected in the first year of a degree restructure. Two hundred and ninety three students (83%) completed their high schooling in Western Australia, and 62 (17%) completed their high schooling elsewhere. Two hundred and thirteen students (60%) had already completed an engineering foundation unit, 86% reporting the previously completed unit to be ENSC1001, Global Challenges. For the remainder, 141 or 40%, this was their first experience of studying an engineering foundation unit. One hundred and twenty students (34%) were studying another engineering foundation unit at the same time as studying the Materials unit, with the remainder, 237 or 66%, stating this was the only engineering foundation unit they were studying that semester.

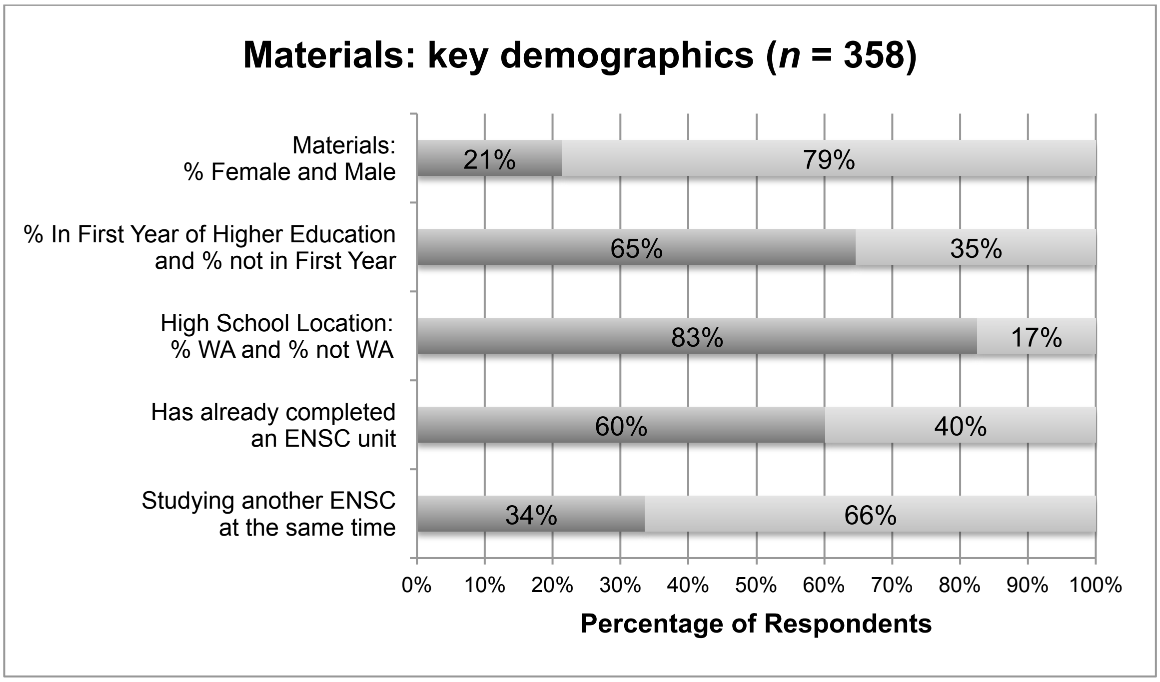

Figure 4.1 Materials survey respondents - key demographic data

4.2.1.2 Motion

Figure 4.2 presents some of the key demographic features of the survey respondents in the Motion unit. Of the 125 completed surveys, 31 (25%) were female, and 94 (75%) were male. Motion was developed as a Level 2 unit, and in contrast to the materials unit, a Level 1 unit, only 3 students (2%) were in their first year of higher education, with the remaining 120 (98%) in their second year or later. One hundred students (80%) completed their high schooling in Western Australia, and 25 (20%) completed their high schooling elsewhere. One hundred and ten students (89%) had already completed an engineering foundation unit, and for 14 students or 11%, this was their first experience of studying an engineering foundation unit. Fifty-two students (48%) were studying another engineering foundation unit at the same time as studying the Motion unit, with the remainder, 73 or 58%, stating this was the only engineering foundation unit they were studying that semester.

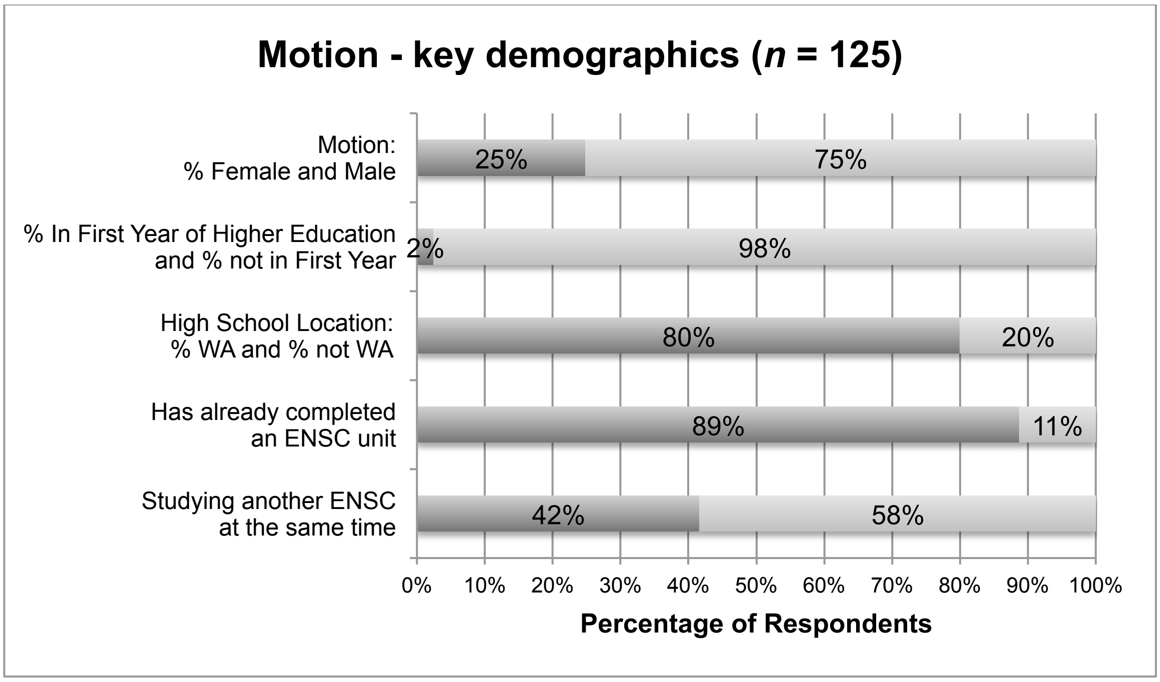

Figure 4.2 Motion survey respondents - key demographic data

4.2.1.3 Energy

Figure 4.3 presents some of the key demographic features of the survey respondents in the Energy unit. Of the 93 completed surveys, 19 (20%) were female, and 74 (80%) were male. Energy, like Motion, was developed as a Level 2 unit, and only 4 students (4%) were in their first year of higher education, with the remaining 89 (96%) in their second year or later. Eight five students (91%) completed their high schooling in Western Australia, and 8 (9%) completed their high schooling elsewhere. Sixty eight students (75%) had already completed an engineering foundation unit, and for 23 students or 25%, this was their first experience of studying an engineering foundation unit. Thirty one students (33%) were studying another engineering foundation unit at the same time as studying the Energy unit, with the remainder, 62 or 67%, stating this was the only engineering foundation unit they were studying that semester.

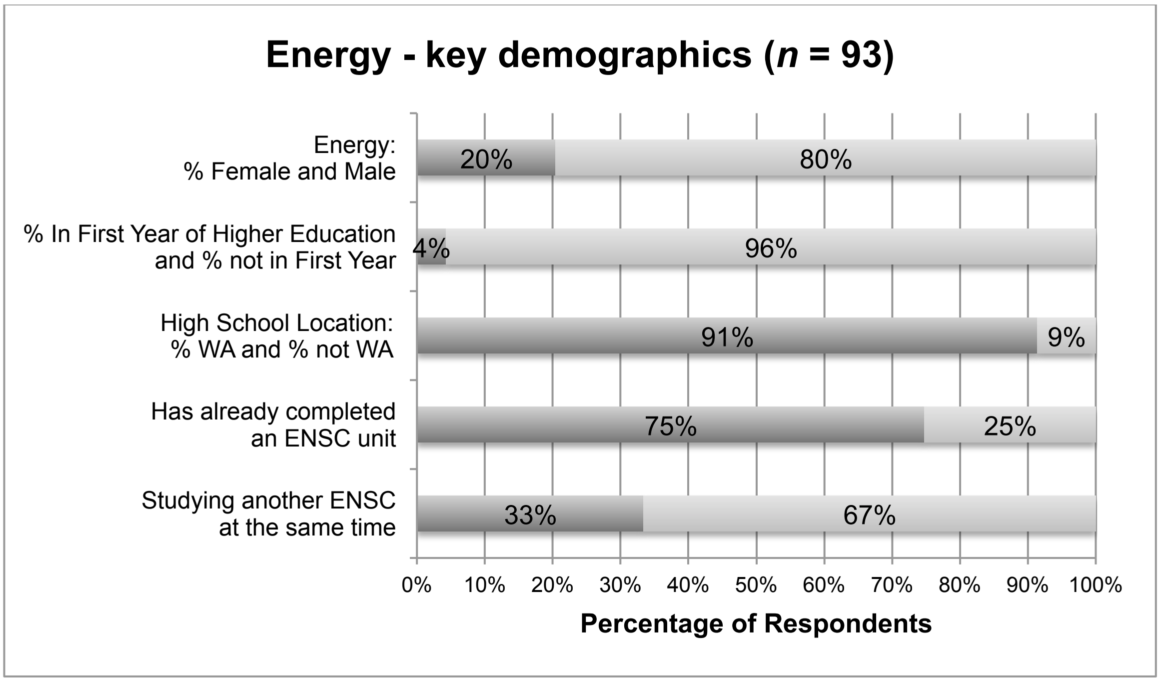

Figure 4.3 Energy survey respondents - key demographic data

One surprising aspect of the demographic features of the survey respondents was the small percentage of international students. In total, 95 of the 576 useable surveys (16%) reported completing their high schooling outside Western Australia. Eleven students completed their high schooling in Eastern Australia. The remaining 84 students (15%) are classified as international students, and although not every international student specified their country of high school, of those who did the countries of origin were: China (28); Malaysia (13); USA (7); South Africa (4); with 2 each from India and Singapore, and one each from Brunei, Colombia, Hong Kong, Indonesia, Iran, Jordan, Korea, Spain, United Arab Emirates, Vietnam and Zimbabwe. More female students than international students completed the survey in each unit.

4.2.2 Part B: Your Preparation for the Engineering Foundation Classes

Part B of the questionnaire sought to capture the range of activities and amount of time students expended in preparation for their two hour classes. Students were asked how much time they typically spent preparing for their two hour classes, what activities they undertook, whether they came across something that was unclear to them, what it was, what they did to help their understanding, and finally, reflecting on what worked very well, and what did not work.

4.2.2.1 Preparing for class

In this unit, students are required to complete a number of specified pre-class activities in preparation for their in-class activities. These classes are (i) Information Sessions (IS) and (ii) Workshops or Practicals. Question B1 asked how many hours a week was typically spent preparing for the IS. As shown in Figure 4.4, the most common time spent in preparation for each unit was around 2 hours a week. A note of frustration may be inferred from the energy student who claimed 30 hours of preparation each week.

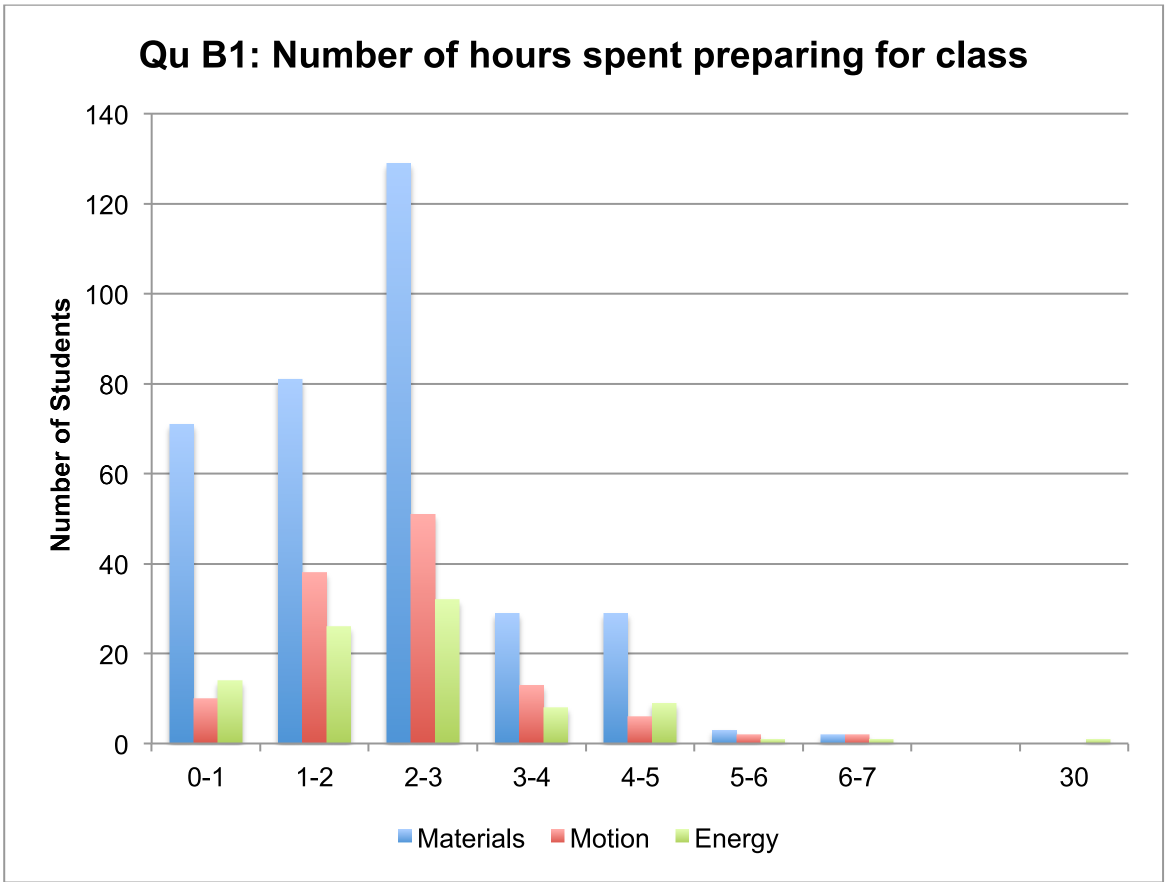

Figure 4.4 Number of hours in preparation for class

Question B2 then sought to identify the types of preparation activities undertaken by the students. A list of seven options was presented, with an ‘Other’ option available. More than one option could be chosen. The results for the three units are presented below.

The three engineering foundation units were each presented slightly differently. Materials employed a traditional lecture / tutorial format. Motion did not deliver lectures, the teaching experience focused through the 2 hour interactive sessions. Energy presented a large group session which, although called a lecture, was explained as a non-compulsory overview session, where the unit coordinator highlighted the key readings for the following week, explained troublesome terminology and went though some key ideas and examples that students had previously found difficult. Scheduled at 4 pm on a Thursday, the unit coordinator emphasised that attendance was not required, that the recording of his presentation was available as a resource to guide the following week's activities, and even offered pizza to those who attended.

The three most frequent preparation activities undertaken by survey participants in materials were attending or watching the lecture; going through the lecture notes and accessing LMS. In Motion, the unit with no lectures, the three most frequent preparation activities were accessing LMS, reading all the background readings and working through the practice questions. In Energy, which offered a large group overview session, the three most frequent preparation activities were also accessing LMS, reading all the background readings and working through the practice questions. A summary of the preparation activities undertaken is presented in Figure 4.5.

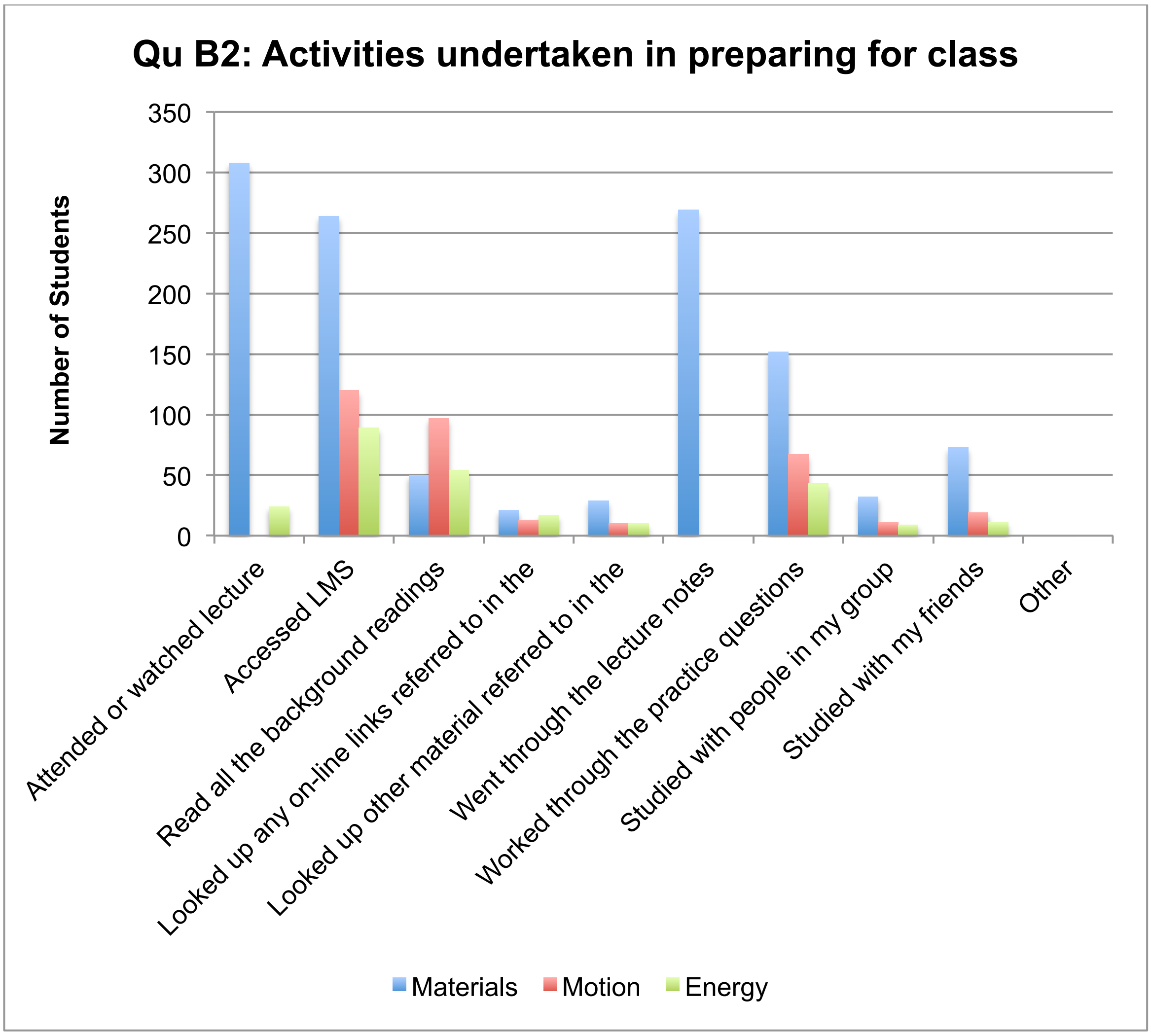

Figure 4.5 Activities undertaken in preparing for class

As more than half of the survey respondents in the Materials unit were in their first year of higher education, a comparison between the preparation habits of the first years and their more senior peers was undertaken. As shown in Figure 4.6, both groups of students tended to undertake the same preparation activities, although first year students attended or watched the lecture (92% vs 78%), went through the lecture notes (79% vs 71%) and studied with their friends (23% vs 16%) more than their more senior peers.

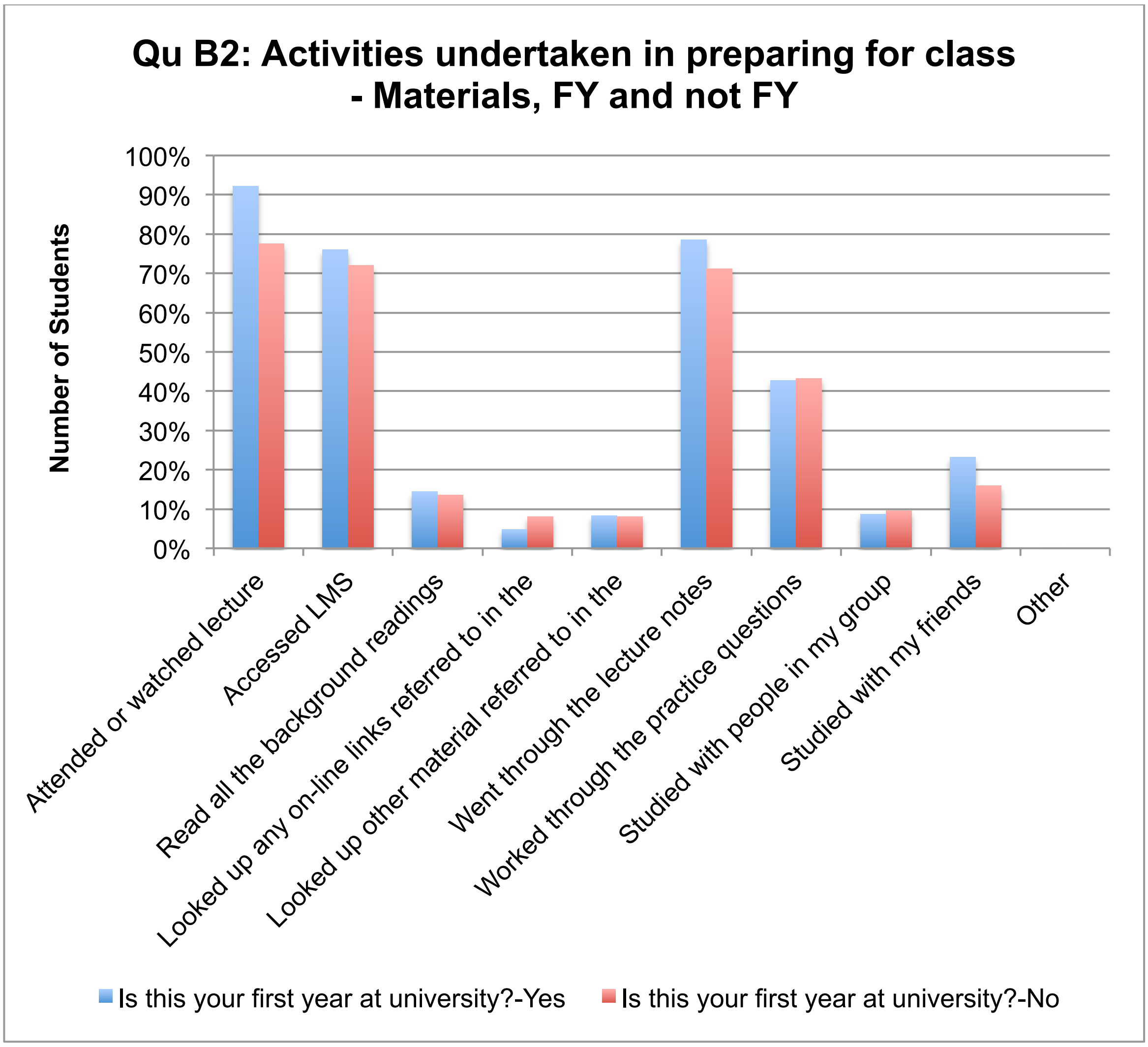

Figure 4.6 Activities undertaken in preparing for class – materials, FY and not FY

4.2.2.2 Working to understand an unclear topic – what was tried

Question B3 asked whether there was something in this week's Information Session that wasn't clear to them, and what it was. Only around a quarter of the students (139 out of 523 responses to this question, or 27%) stated that they found something unclear in the current week's Information Session. The total number of responses by unit, and what the students found unclear, is listed in Table 4.1. In Materials, the most unclear topics were around shear force diagrams and bending moment diagrams, whereas no pattern was discerned in the Motion and Energy units.

Table 4.1 Qu B3 – answers to what was unclear

Was there something in this week's Information Session that *wasn't* clear to you?	ENSC 1002 Materials	ENSC 2001 Motion	ENSC 2002 Energy
Yes	70	49	20
No	255	67	62

	ENSC 1002 Materials	ENSC 2001 Motion	ENSC 2002 Energy
What wasn't clear?	a type of question	A problem	a lot
	About how to determine the moment	an = rtheta	Application questions
	About the area of quizes and content that they taught	Answer to a practice question was not what I had.	But a lot in previous weeks
	Bending moment	calculation	Everything
	Bending moment diagrams	cleer[?] information on topic	How the stakeholder meeting was going to progress, what groups were doing when.
	Bending moment, stress and strain	curvilinear motion	Just generally what was going on.
	Bending moments, etc	difference between moments and inertia	new topic on photovoltaic cells
	BMD SFD	Everything	phasor circuits
	Calculation of Mmax according to the graph	few concepts e.g., relative motion	Q3 - solar cell connected to car battery
	Considering the distance to the load or before the load when finding shear & M.	how to use formulas and when	Question 2
	designing bridge and failure	I found it difficult	team presentation topics
	Didn't really understand the bending calculations	Inductors and capacitors	The team presentation
	distributed loads on beams & calculating its shear force	Inductors and capacitors	Wind turbines
	due to missing everything I struggle	Mass transfer	Worked examples
	Everything (no idea how to solve the problems).	methodology	Worked examples
	Got explained	moment of inertia	
	How bending moment diagrams are drawn	motion equations	
	How to do much harder questions on topic	nodal analysis	
	How to do the questions	notation	
	how to draw the diagram, how many cut do we have to use	Part 3	
	How to finish a quiz problem	Relative motion	
	How to know where to cut for BMD / SFD's	relative motion	
	internal forces	some of the equations were complex	
	It's hard to see the picture clearly on the board	some of the ways formulas were found some practice questions	
	method of sections	some problem	
	Most of it	sometimes, no much details it makes harder to read and understand	
	Note enough example	The method of solving those worked examples	
	Qst 1	the readings	
	shear & moment diagrams	Theories behind formulas	
	shear force	very hard explanation for info sesh 6 qu 1 & 2	
	shear force & bending moments	Week 5 material	
	Shear forces	what specific info needed	
	Shear forces	Where the g+ term was derived from in N-T coordinates	
	shear forces	why they must make the content so ambiguous and long	
	Shear forces		
	Sheariing force with torque over are		
	Some of the concepts		
	some parts of concepts		
	stress and yield in relation to the table thingy		
	stress calcs		
	Stupid bending moment diagram		
	The answers in the test we did, think I got it wrong.		
	the beams		
	The formula for stress (and the constants involved).		
	The majority of the examples		

	the test	winded
	tutor doesn't go through questions thoroughly	
	Unsure of background readings	
	vary loads	
	working out maximum dendry[?]	

Survey respondents were presented with a list of possible activities to help understand an unclear topic, and asked to select which ones they used. The responses from all three units are shown in Figure 4.7, and from the individual units in Figures 4.8, 4.9. 4.10 and 4.11. In the Materials unit, the most frequent activities undertaken by students to understand an unclear topic were to watch a lecture from this university, ask their friends and look up a text book. In Motion, the most frequent activities were to use Google, ask friends and look up Wikipedia. Even though no lectures were presented in this unit, 8 Motion students watched a lecture from this university. A possible explanation is that these students had older siblings or friends who had recordings of a previous incarnation of the unit. In Energy, the three most frequent activities were to use Google, watch the 'lecture' and to look up Wikipedia, with a fourth being to ask people in their group rather than their friends. Very few students posted or reviewed questions on a forum, consulted the unit coordinator, looked up a book that was not a text book, asked someone who was not a friend or not in their group or watched a lecture on this topic from another university (MOOC (Massive Open Online Course)), although one Energy student wrote that he used Youtube Khan Academy and found it "More helpful than most UWA staff" (ID E86).

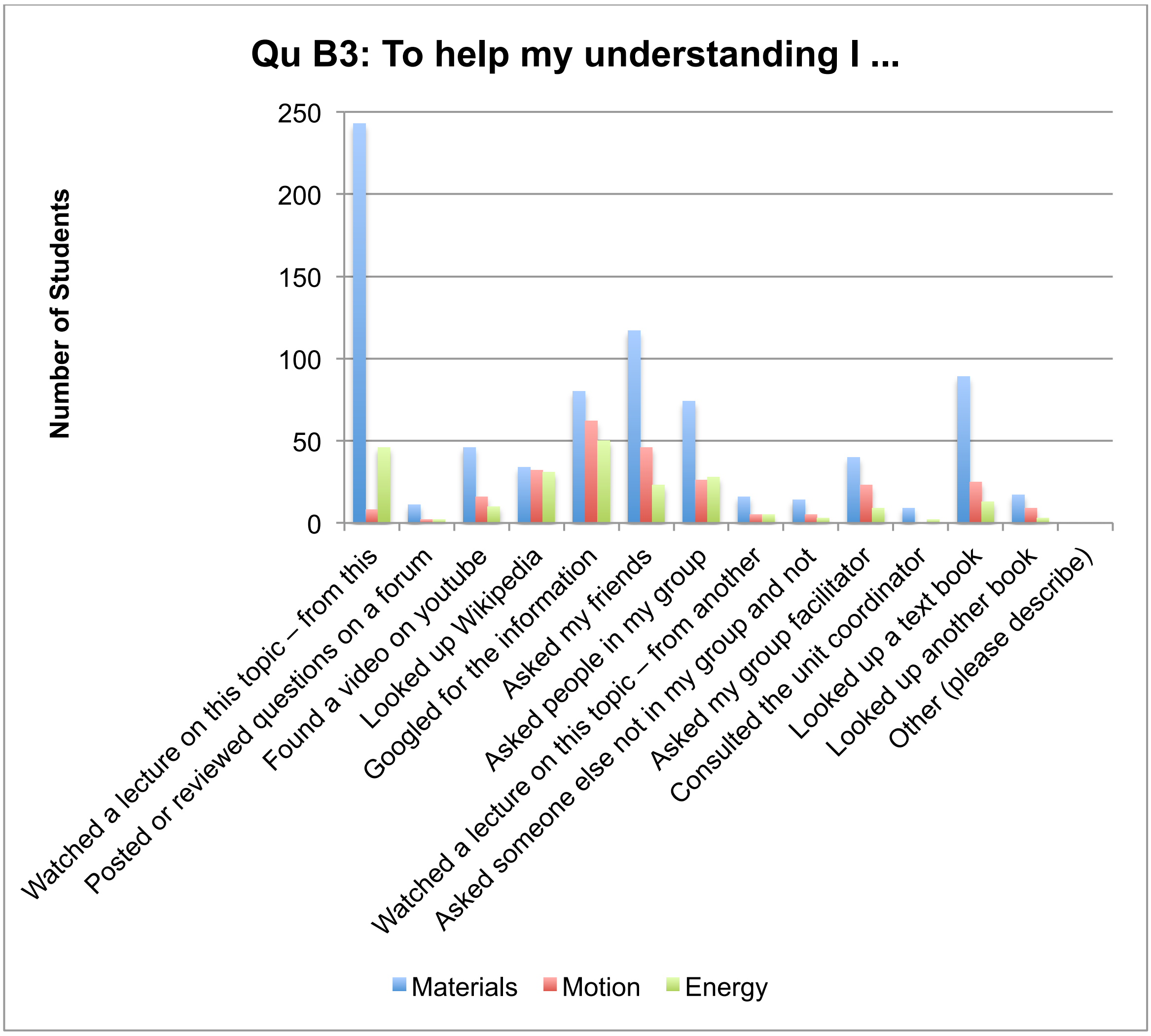

Figure 4.7 Activities undertaken to help student understanding

As more than half of the survey respondents in the Materials unit were in their first year of higher education, a comparison between the approaches to unclear topics of the first years and their more senior peers was undertaken. As shown in Figure 4.8, first year students were more likely to watch the lecture (75% vs 57%), ask their friends (39% vs 22%) and ask people in their groups (24% vs 16%) than their more senior peers. This suggests that students not in their first year are more likely to adopt a more independent approach to trying to understand an unclear topic.

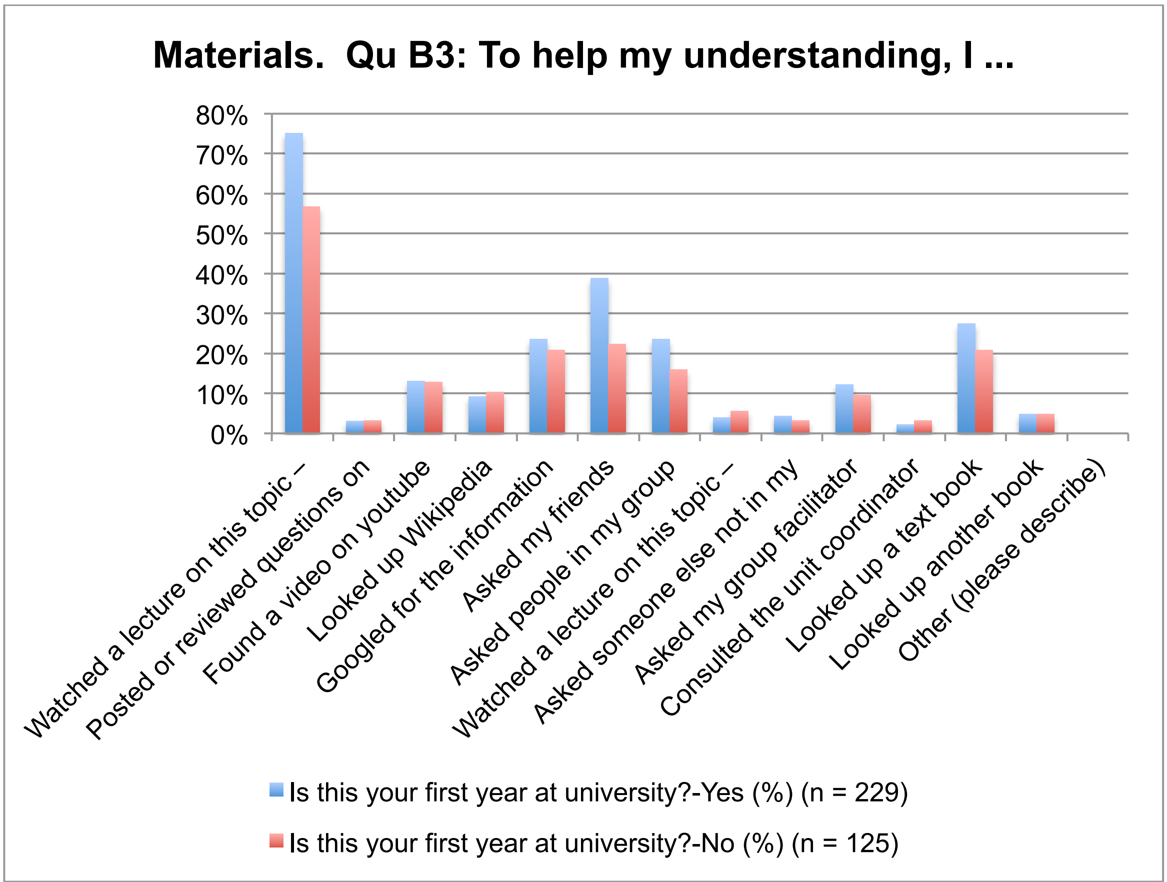

Figure 4.8 Materials: FY and not FY. To help my understanding I ...

Secondly, the responses of those who had not previously completed an ENSC unit were compared with those who had. First time ENSC students studying Materials were more likely to use Google, text books and other books to work through trying to understand an unclear topic. On the other hand, student who had previously completed an ENSC unit were more likely to ask others (friends or group members) and watch a lecture or video. This comparison is shown in Figure 4.9.

The same comparison, between the responses of first time ENSC students and those who had completed an ENSC unit, was also undertaken in the Motion and Energy units. As shown in Figure 4.10, first time ENSC students studying Motion were more likely to watch a lecture or video, look up Wikipedia, and look up a non-text book. On the other hand, student who had previously completed an ENSC unit were more likely to use Google, ask their friends or the group facilitator. First time ENSC students tended to work solo in working through an unclear topic; those who had previously completed an ENSC unit tended to employ their group and wait until their Information Session to ask the facilitator.

The comparison between the responses of first time ENSC students and those who had completed an ENSC unit, in Energy showed a few differences. First time ENSC students studying Energy were more likely to watch a lecture, look up Wikipedia and Google, and look up a text book. On the other hand, student who had previously completed an ENSC unit were more likely ask their friends, those in their group or the group facilitator. Once again, first time ENSC students tended to work solo in working through an unclear topic; those who had previously completed an ENSC unit tended to involve the resources of others – their friends, their group and their facilitator – to help them make clear an unclear topic.

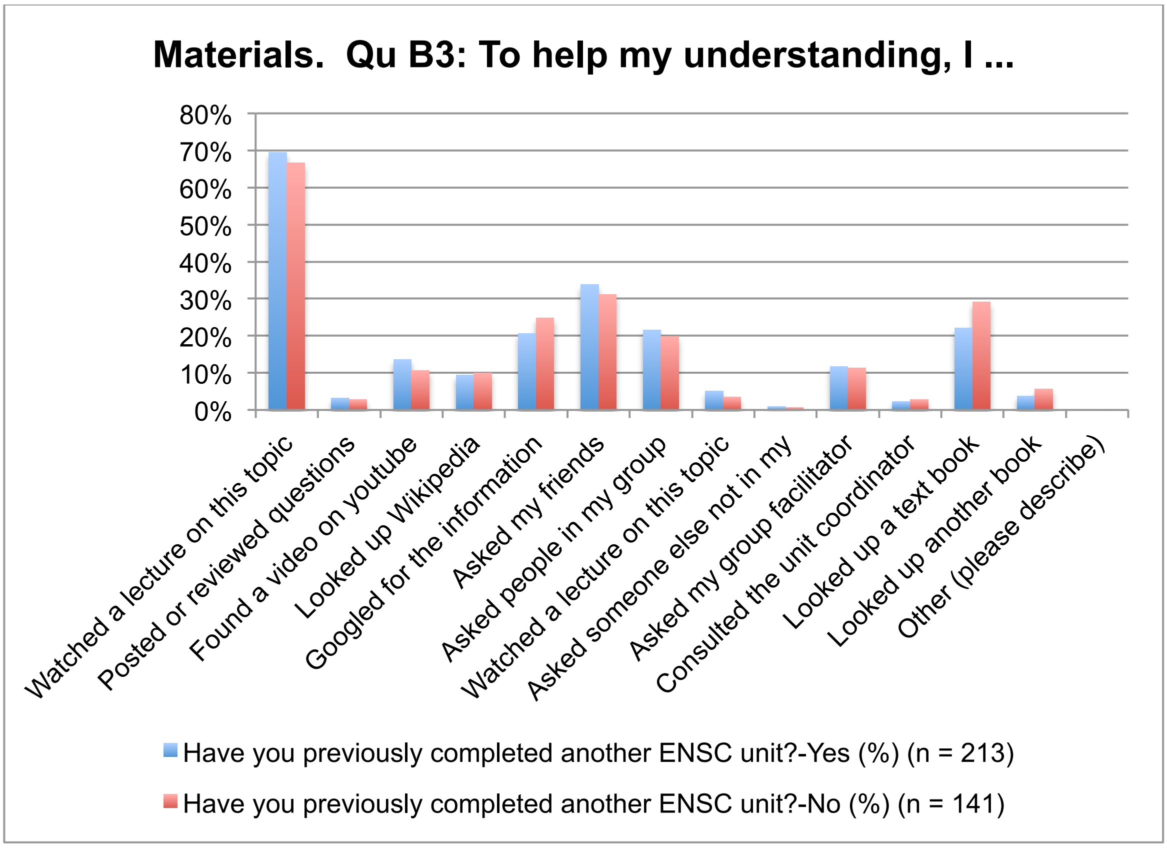

Figure 4.9 Materials - to help my understanding I ... (new and not new to ENSC units)

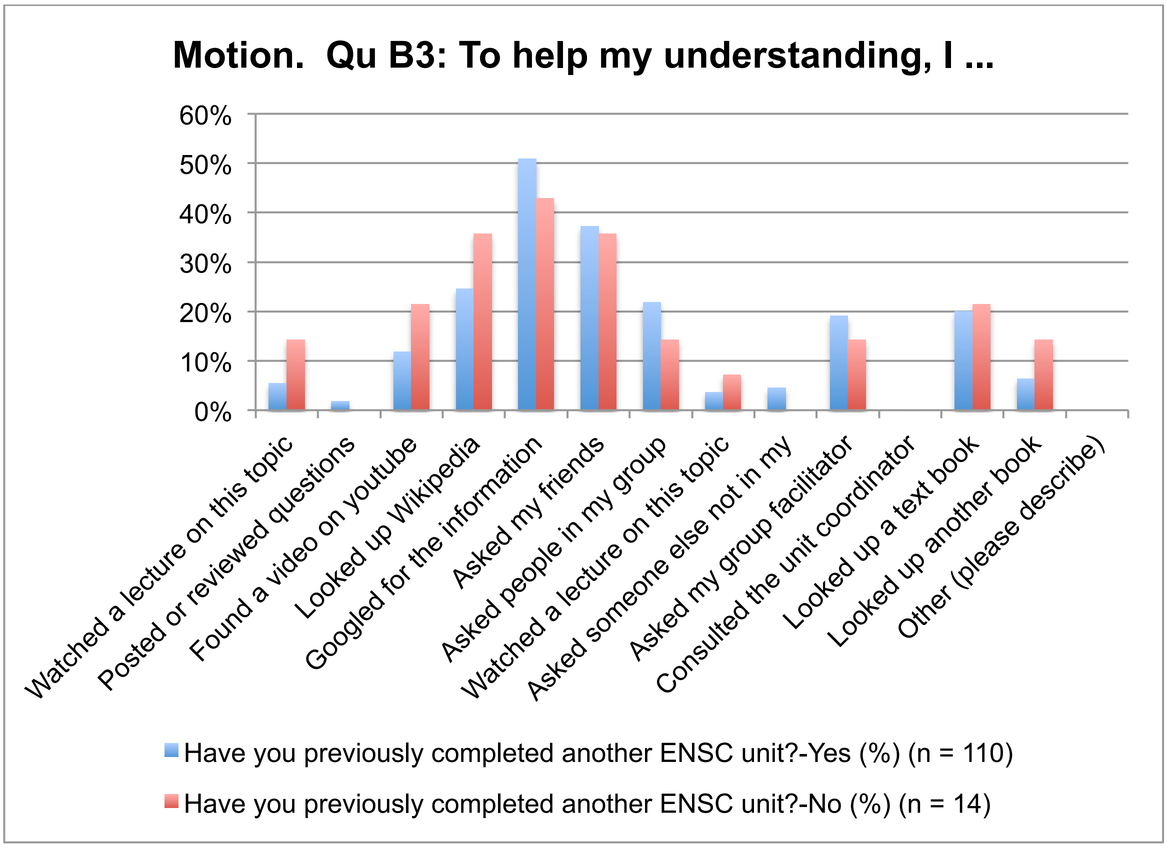

Figure 4.10 Motion – to help my understanding I ,,, (new and not new to ENSC units)

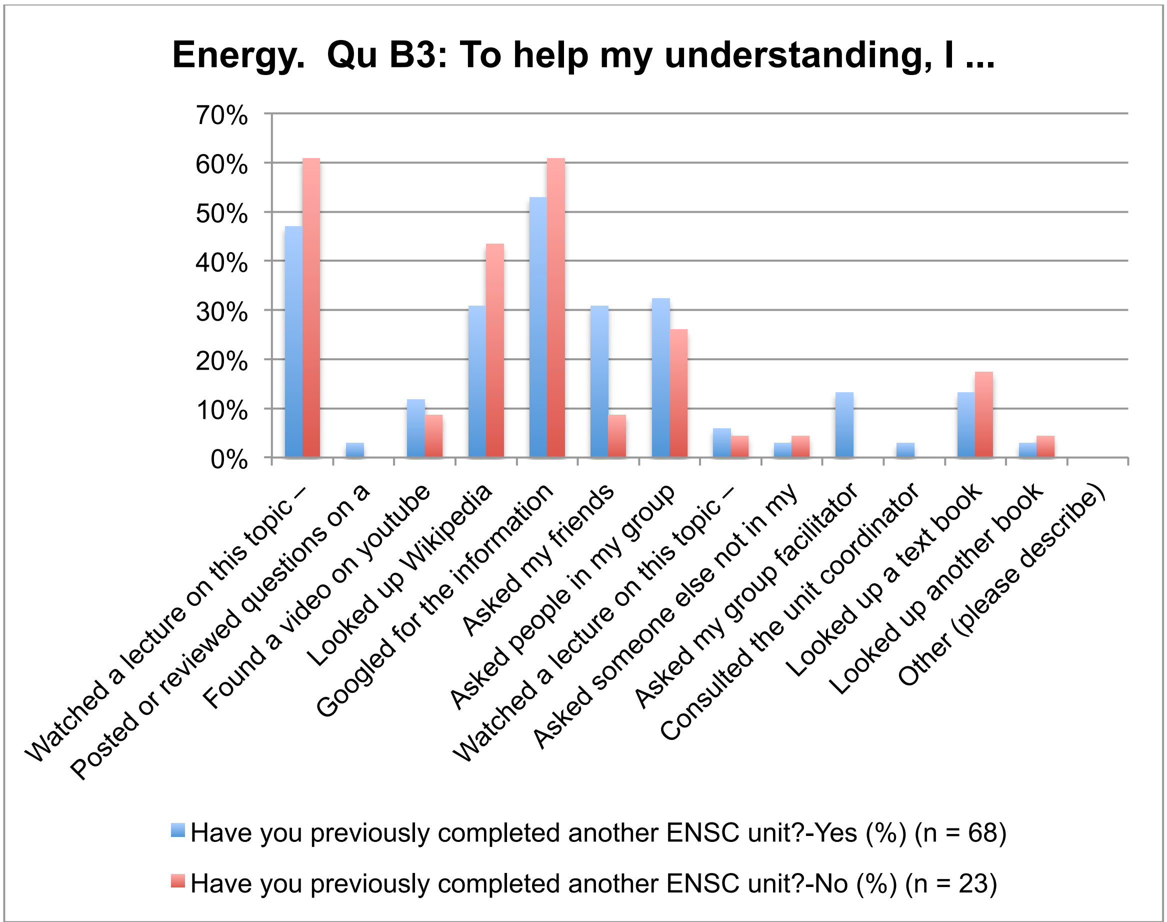

Figure 4.11 Energy – to help my understanding I ,,, (new and not new to ENSC units)

4.2.3 Part C. In Class and After

Part C, In Class and After, consisted of two items. The first item asked about the importance of various aspects around learning in class (e.g., "When thinking about your learning in class, how important is – working with group members?"), using five-point Likert scales. Six aspects were listed, as well as "Other". The second item asked how many hours a week after the class was typically spent consolidating knowledge and completing homework.

Students in all three units rated the following aspects as important: working with their group members and having completed the required exercises. The most important aspect for all three units was the worked examples on the boards by the facilitator. Less important were the worked examples on the boards by other students. The explanations of the facilitator were also seen as very important. Completing the pre-reading was acknowledged as important for Motion and Energy students, but as mostly as neither important nor important by Materials students. Scatter diagrams of the responses to these Likert Scale questions are presented in Appendix 7.

Question C2 asked how many hours a week after the class was typically spent consolidating knowledge and completing homework. Most students dedicated no more than three hours a week to their after class learning activities, with Materials students most commonly spending 1 hour, Motion students 2 hours and Energy students 3 hours. This reflects the increasing difficulty of the units and a greater abstract content in Energy, as well as the requirement to submit written lab reports.

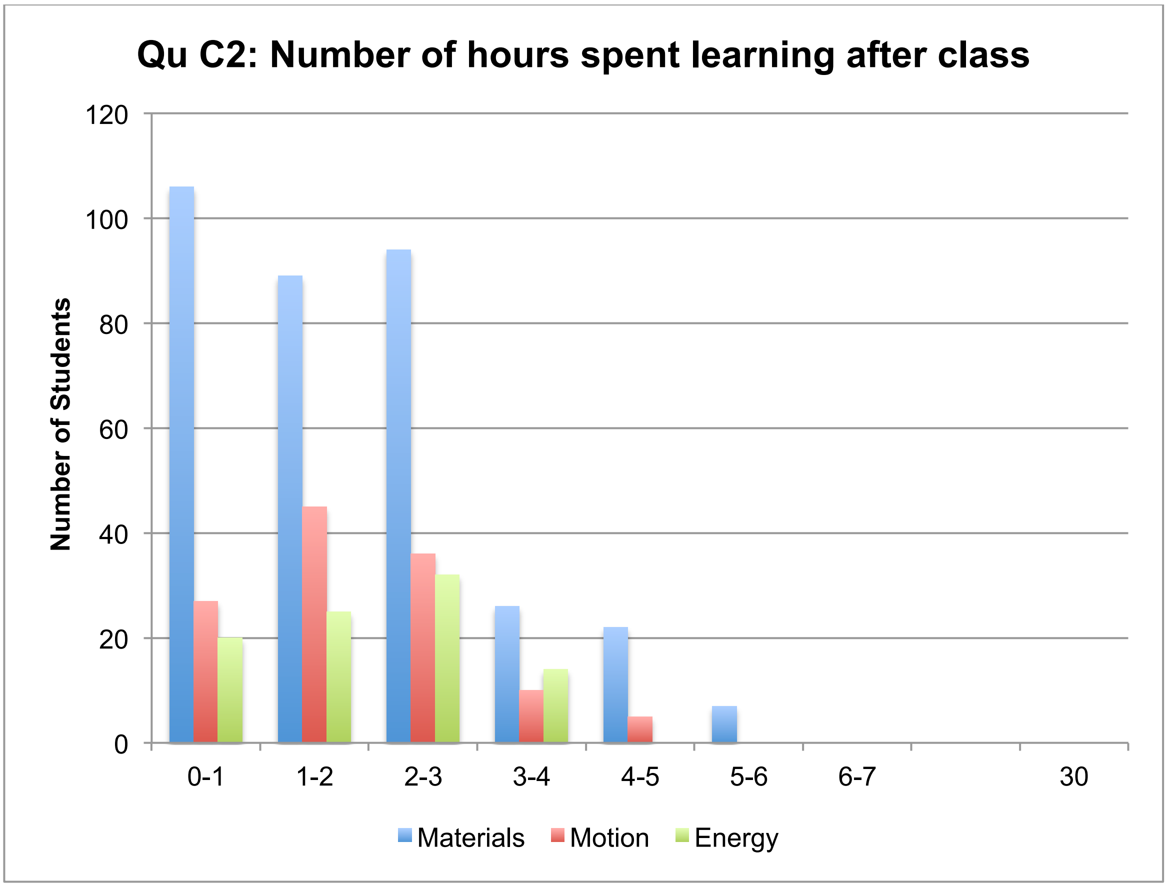

Figure 4.12 C2. Typical hours / week in learning activities after the classes.

4.2.4 Part D. Your Experience of Threshold Concepts and Understandings

Part D of the questionnaire, Your Experience of Learning Threshold Concepts and Understandings, presented the unit specific threshold concepts (TC) as well as the four common engineering threshold concepts and sought how the students felt about each concept. Up to Week 6 of Semester, only a few threshold concepts had been addressed. The threshold concept short cut codes, and how the TC was described in the questionnaire, are listed in Table 4.2. The three unit specific threshold concepts in Materials were *Modelling*, *Equilibrium*, and *Stress / Strain*. In Motion, the three unit specific threshold concepts were *Modelling*, *System Identification* and *Conservation Laws*. The five unit specific threshold concepts in Energy were *Modelling*, *Language*, *System Identification*, *Phasors* and *Power*.

The four common threshold concepts were *Self-Driven Learning, Communication, Leadership* and *Teamwork*. These are described in Table 4.3.

Part D asked students three questions about each threshold concept encountered by Week 6 of semester. For the unit specific threshold concepts, the three questions asked how the student felt about the level of difficulty of the threshold concept, the amount of time allocated to learning the concept and their level of confidence around applying the concept. Survey respondents were presented with a continuous scale with different legends:

1. How hard was this concept? (Really Hard to Not Hard at all)
2. Was enough time allocated in this unit to enable you to learn this concept? (Need More Time to Prefer Less Time)
3. How confident do you feel about applying this concept to the material covered so far in this unit? (Very confident to Not confident at all)

For the common threshold concepts, the three questions were different. The student was asked about their perceived importance of the threshold concept, an assessment of their growth in ability around this threshold concept, and their level of confidence around their effectiveness in applying the concept. Survey respondents were presented with a continuous scale with different legends. Using the common TC *Teamwork* as an example, the questions were:

1. How **important** do you believe *teamwork* is to successful engineering practice? (Very Important to Not at all important)
2. Since the start of this unit, I have gained a greater **ability** to be a *team player*. (Strongly Agree to Strongly Disagree)
3. How confident do you feel about your abilities to be an **effective** *team player*? (Very confident to Not confident at all)

Some students did not use the scale as a continuous scale, but showed their responses on just three points: beginning, middle and end points. A few just circled the middle of the scale for all their responses, but the majority of responses to these questions used the scale as continuous. Graphs of the results are presented in Appendix 8, and summaries of the results are presented in the following sections.

Table 4.2 Threshold Concepts surveyed in the Week 6 questionnaire.

TC Code	TC as described in: ENSC 1002 Materials	TC as described in: ENSC 2001 Motion	TC as described in: ENSC 2002 Energy
Modelling	Simplifying a physical system for analysis by choosing an appropriate *model* (e.g., a mathematical model).	In solving a circuit problem (identifying the voltages, currents, etc), the circuit can be simplified for analysis by choosing an appropriate circuit *model*.	In solving a circuit problem (identifying the voltages, currents, etc) the circuit can be simplified for analysis by choosing a appropriate circuit *model* (Thevenin, Norton).
Equilibrium	All systems and their parts tend to equilibrium		
Stress / /Strain	The relationship between stress and strain		
System Identification		Identifying and defining the *system* (noting system boundaries) is a useful starting point in analysing and simplifying a system	Taking any circuit and drawing a dividing line across two points (identifying and defining the *system*), viewing / replacing one side of the circuit with its Thevenin/Norton equivalent and considering the other side as the "load".
Conservation Laws		Conservations laws can be used to analyse a system. For example, conservation laws for charge and energy can be used to analyse electrical circuits.	
Language			In solving a circuit problem (identifying the voltages, currents, etc), there is a *standard language* for *drawing* and *representing* the circuit.

	Redrawing the circuit by rearranging the nodes and branches makes circuit analysis easier.
Phasors	Phasors for analysis of AC circuits
Power	Reactive Power: vs Real Power and Complex Power

Table 4.3 Common Threshold Concepts

TC Code	As described in all three questionnaires:
Self-Driven Learning	*Self - driven Learning*. e.g., there are different ways to learn and from different sources
Communication	*Communication* - two - way, effective communication in many forms is critical to engineering practice
Leadership	*Leadership* - Engineers spend much of their time coordinating the work of people over whom they might have no direct authority
Teamwork	*Teamwork* – Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone

4.2.4.1 Materials

The questionnaire for materials questioned student experiences around seven threshold concepts. Three threshold concepts (*Modelling, Equilibrium, Stress / Strain*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in Appendix 8.

4.2.4.1.1 Modelling

Question D1 asked about the TC *Modelling*: Simplifying a physical system for analysis by choosing an appropriate *model* (e.g., a mathematical model) and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Modelling* neither hard nor easy, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.1.2 Equilibrium

Question D2 asked about the TC *Equilibrium*: All systems and their parts tend to equilibrium, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Equilibrium* more easier than hard, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.1.3 Stress / Strain

Question D3 asked about the TC *Stress / Strain*: The relationship between stress and strain, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Stress / Strain* more harder than easier, preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.1.4 Self Driven Learning

Question D4 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources"*, three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*.

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, neither agreed nor disagreed that their ability to self-drive their learning had increased since the start of this unit, and felt confident in their abilities to be an effective self-driven learner.

4.2.4.1.5 Communication

Question D5 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice"*, three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*?

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective communicator.

4.2.4.1.6 Leadership

Question D6 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority"*, three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*?

Students acknowledged the importance of the TC *Leadership* to successful engineering practice, agreed more than disagreed that their ability to lead had increased since the start of this unit, and felt strongly confident in their abilities to be an effective leader.

4.2.4.1.7 Teamwork

Question D7 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone"*, three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*?

Students acknowledged the importance of the TC *Teamwork* to successful engineering practice, agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and felt strongly confident in their abilities to be an effective team player.

4.2.4.1.8 Summary – Materials TC

At this stage of the Semester, students reported finding the unit specific threshold concepts as being neither hard nor easy, had no preference around allocating more or less time to the TCs in the units, and felt confident in their abilities to apply the TC to the material covered so far in the unit. Students acknowledged the importance of the four common engineering TCs, *Self-Driven Learning, Communication, Leadership* and *Teamwork*, and felt confident in their abilities in those four areas. They acknowledged a slight growth in their abilities in the four common engineering TCs since the start of the unit.

4.2.4.2 Motion

The questionnaire for Motion also questioned student experiences around seven threshold concepts. Three threshold concepts (*Modelling, System Identification* and *Conservation Laws*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in Appendix 8.

4.2.4.2.1 System Identification

Question D1 asked about the TC *System Identification*: Identifying and defining the *system* (noting system boundaries) is a useful starting point in analysing and simplifying a system and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? This TC was also part of the Energy unit.

Students reported finding the TC *System Identification* neither hard nor easy, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.2.2 Modelling

Question D2 asked about the TC *Modelling*: In solving a circuit problem (identifying the voltages, currents, etc), the circuit can be simplified for analysis by choosing an appropriate circuit *model,* asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Modelling* slightly harder than easier, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.2.3 Conservation Laws

Question D3 asked about the TC *Conservation Laws*: Conservations laws can be used to analyse a system - for example, conservation laws for charge and energy can be used to analyse electrical circuits and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Conservation Laws* neither hard nor easy, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.2.4 Self Driven Learning

Question D4 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources"*, three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*?

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, agreed that their ability to self-drive their learning had increased since the start of this unit, and most felt confident in their abilities to be a an effective self-driven learner.

4.2.4.2.5 Communication

Question D5 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice"*, three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*?

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt confident in their abilities to be a an effective communicator.

4.2.4.2.6 Leadership

Question D6 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority"*, three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*?

Students acknowledged the importance of the TC *Leadership* to successful engineering practice, neither agreed nor disagreed that their ability to lead had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective leader.

4.2.4.2.7 Teamwork

Question D7 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone"*, three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*?

All students acknowledged the importance of the TC *Teamwork* to successful engineering practice, more students agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and almost all students felt strongly confident in their abilities to be an effective team player.

4.2.4.2.8 Summary – Motion TC

None of the three unit TCs - *System Identification, Modelling*, and *Conservation Laws* were experienced by students as hard, although *Modelling* was found to be slightly harder than easier, and students would have preferred more time on *Conservation Laws*. Students felt confident applying all three TCs to the material covered so far in the unit.

All students agreed that the four common engineering threshold concepts, *Self-Driven Learning*, *Communication*, *Leadership* and *Teamwork*, were important to engineering practice, and most felt confident to very confident with their skills in these areas. They acknowledged growth in their abilities in the four common engineering TCs since the start of the unit.

4.2.4.3 Energy

The questionnaire for Energy queried students' experiences around nine threshold concepts. Five threshold concepts (*Modelling*, *Language, System Identification*, *Phasors* and *Power*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in Appendix 8.

4.2.4.3.1 Modelling

Question D1 asked about the TC *Modelling*: In solving a circuit problem (identifying the voltages, currents, etc) the circuit can be simplified for analysis by choosing a appropriate circuit *model* (Thevenin, Norton), asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? This TC was part of all three units, Materials, Motion and Energy.

Students reported finding the TC *Modelling* neither hard nor easy, had a preference for more time, and in general felt confident applying this TC to the material covered so far in this unit.

4.2.4.3.2 Language

Question D2 asked about the TC *Language*: In solving a circuit problem (identifying the voltages, currents, etc), there is a *standard language* for *drawing* and *representing* the circuit - redrawing the circuit by rearranging the nodes and branches makes circuit analysis easier, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Language* neither hard nor easy, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

4.2.4.3.3 System Identification

Question D3 asked about the TC *System Identification*: Taking any circuit and drawing a dividing line across two points (identifying and defining the *system*), viewing / replacing one side of the circuit with its Thevenin/Norton equivalent and considering the other side as the "load", asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? This TC was also part of the Motion unit.

Students reported finding the TC *System Identification* harder than easier, would have preferred more time, and felt neither confident nor not confident applying this TC to the material covered so far in this unit.

4.2.4.3.4 Phasors

Question D4 asked about the TC *Phasors*: Phasors for analysis of AC circuits, and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.

Students reported finding the TC *Phasors* hard, the hardest TC encountered so far. All students sought more time to engage with the TC *Phasors*. Most students did not feel confident applying this TC to the material covered so far in this unit.

4.2.4.3.5 Power

Question D5 asked about the TC *Power*: Reactive Power: vs Real Power and Complex Power, and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

Students reported finding the TC *Power* hard, would have preferred more time, and in general did not feel confident applying this TC to the material covered so far in this unit.

4.2.4.3.6 Self Driven Learning

Question D6 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources"*, three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*?

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, neither agreed nor disagreed that their ability to self-drive their learning had increased since the start of this unit, and felt confident in their abilities to be an effective self-driven learner.

4.2.4.3.7 Communication

Question D7 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice"*, three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*?

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective communicator.

4.2.4.3.8 Leadership

Question D8 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority"*, three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*?

All students acknowledged the importance of the TC *Leadership* to successful engineering practice. Most students agreed more than disagreed that their ability to lead had increased since the start of this unit, and most students felt strongly confident in their abilities to be an effective leader.

4.2.4.3.9 Teamwork

Question D9 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone"*, three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*?.

All students acknowledged the importance of the TC *Teamwork* to successful engineering practice. Most students agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and all students felt confident in their abilities to be an effective team player.

4.2.4.3.10 Summary – Energy TC

Two threshold concepts were clearly identified by students as hard – *Phasors* and *Power*. (See their description in Table 4.2). Students sought more time to learn these concepts, and did not yet feel confident in applying these concepts to the material covered so far in the unit. The TC *System Identification* was experienced as hard, but students felt confident in applying the concept. The other two unit TCs, *Modelling* and *Language*, were experienced as neither hard no easy, with students reporting moderate confidence in applying the concepts.

All students agreed that the four common engineering threshold concepts, *Self-Driven Learning, Communication, Leadership* and *Teamwork*, were important to engineering practice, and most felt confident to very confident with their skills in these areas. They acknowledged a slight growth in their abilities in the four common engineering TCs since the start of the unit.

4.2.4.4 Summary – Difficulty, Importance, Timing and Confidence with Threshold Concepts

By Week 6 of a 13 week Semester, eight unit specific threshold concepts and four common threshold concepts had been explored in the three Engineering foundation units Materials, Motion and Energy. None of the Materials TC were described as hard, one of the three Motion TCs (*Modelling*) was found to be slightly harder than easier, and two of the five Energy TCs (*Phasors* and *Energy*) were acknowledged as difficult.

When considering the amount of time allocated to a TC at that point in the unit, Materials students preferred neither less nor more time, Motion students preferred a greater time allocation to two of its three unit specific TCs, *Modelling* and *Conservation Laws*, and Energy students preferred a greater time allocation to all five of its unit specific TCs.

Students' level of confidence in applying the TC to the material covered so far in the unit was generally high. Materials and Motion students expressed confidence in applying all their three unit specific TCs. In Energy, students expressed confidence in applying two of their unit specific TCs (*Modelling* and *Language*), felt neither confident nor not confident in applying the TC *System Identification*, and did not feel confident in applying the TCs *Phasors* and *Power*, which had previously been acknowledged as hard.

All students agreed that the four common engineering threshold concepts, *Self-Driven Learning, Communication, Leadership* and *Teamwork*, were important to engineering practice, and most felt confident to very confident with their skills in these areas. They acknowledged a slight growth in their abilities in the four common engineering TCs since the start of the unit.

4.2.5 Part E. Final Comments

The final part of the survey asked survey respondents to write any other comments or suggestions. Some responses were "no", "no comment", "n/a". Excluding these responses, 123 Materials students entered a comment in this field, 40 Motion students provided some feedback, and responses were received from 54 Energy students.

Many of the Motion and Energy students took the opportunity to write detailed and thoughtful responses, most of which are outside the scope of this project addressing their experiences of threshold concepts. The comments in this part tended to relate to their learning experiences as a whole. Materials students' comments ranged from aspects of curriculum such as content (too easy, had covered the content previously under old courses), timing (end the IS with a quiz, rather than start it), pedagogy (difficulty with group work, appreciating lectures), difficulty in finding enough practice questions with answers, and difficulty understanding the English spoken by some facilitators. Motion students' comments covered a similar range, although students expressed concern about the amount of reading that was required and requested the reintroduction of lectures. Energy students' comments centred on feelings of being rushed through the content, the balance between self-learning and facilitator explanations swung too far towards self-learning, difficulty understanding the English spoken by some facilitators, the unit's overall lack of structure, and that groups of five or six were too large.

In accordance with ethics requirements, all the comments were recorded and are listed in Appendix 9.

4.3 Survey Data – Qualitative

4.3.1 Working to understand an unclear topic – what worked / did not work

The final question in Part B, Your Preparation for the Engineering Foundation Classes, invited survey participants to reflect on what they did to learn an unclear topic, and to write what worked very well for them and what did not work. Out of the 358 useable questionnaires in Materials, there were 224 (63%) responses to the question of what worked, and 130 (36%) responses to the question of what did not work. In Motion (n = 125), there were 77 (62%) responses to the question of what worked, and 42 (34%) responses to the question of what did not work. Out of the 93 useable questionnaires in Energy, there were 67 (72%) responses to the question of what worked, and 24 (26%) responses to the question of what did not work.

4.3.1.1 Materials

The most common responses to what worked for students to learn something unclear were doing questions (59), lectures (57), asking (45) and lecture notes (35). Asking included asking a friend (22), the tutor (17), group members (10), people who had already completed the unit (7), and people who knew how to do it (2). A word cloud of the responses to this question is presented in Figure 4.12. The large font size for the work 'Lecture' reflects its appearance in the three phrases lecture, lecture notes and lecture examples.

Figure 4.13 Word Cloud - Materials: what works

The most common responses to what *did not* work for students to learn something unclear were clustered around inactivity, lack of solutions and asking friends. Examples of inactivity included doing nothing, doing only the given lecture examples, not doing the practice problems, not studying, not going to the lecture, just watching the lecture, just reading the notes, just looking through the text book. Survey respondents were clear that engagement with the material was necessary, and acknowledged that a lack of engagement did not work for them. A word cloud of the responses to this question is presented in Figure 4.14.

Figure 4.14 Word Cloud - materials: what doesn't work

For those students who attempted to engage with the material to be learnt, what did not work were questions without solutions. This is summarised in a comment from a first year student:

Attempting questions which have no solutions. Can't see if I'm doing questions right or wrong. (ID M110)

Some students notes that although the text book provided practice questions, these also did not provide solutions:

There was not enough practice questions, done during the lecture, and the text book recommended also has no answers and workings for the questions behind, which is very confusing and unhelpful. (ID M333).

Lack of solutions also included the lecture notes. During the lectures, students used prepared lecture notes with blanks that the students filled in during the lecture. Those who did not attend the lecture, or those revising, noted that the recorded lectures and on line lecture notes contained the unfilled lecture notes. As a first year student noted:

Trying to revise / learn from lecture notes. They are left blank which is not helpful. Would be much better if he uploaded completely filled-out notes. (ID M32)

The third most frequent area cited by students as not working for them to learn an unclear topic was asking friends. Two reasons given were because their friends also did not understand the material, and their friends who had completed the unit in the previous Semester covered different material, not covered in this Semester's unit.

In Materials, the same issues worked and did not work for students to learn an unclear topic. Asking someone worked, as long as it was someone who knew the material. Doing questions worked, as long as there were solutions to provide a check that the process and understandings had been correctly applied. Lectures and lecture notes worked, as long as the lectures and lecture notes contained solutions to example questions and were complete, and as long as the lectures contained clear explanations.

4.3.1.2 Motion

The most common responses to what worked for students to learn something unclear in Motion were using the internet (31), doing questions (18), and asking (14). Using the internet included using Google, Wikipedia, and YouTube including lectures from other universities. Asking included asking a friend, the facilitator, and group members. A word cloud of the responses to this question is presented in Figure 4.15. A statement about what works for this more senior student summarises a large number of responses:

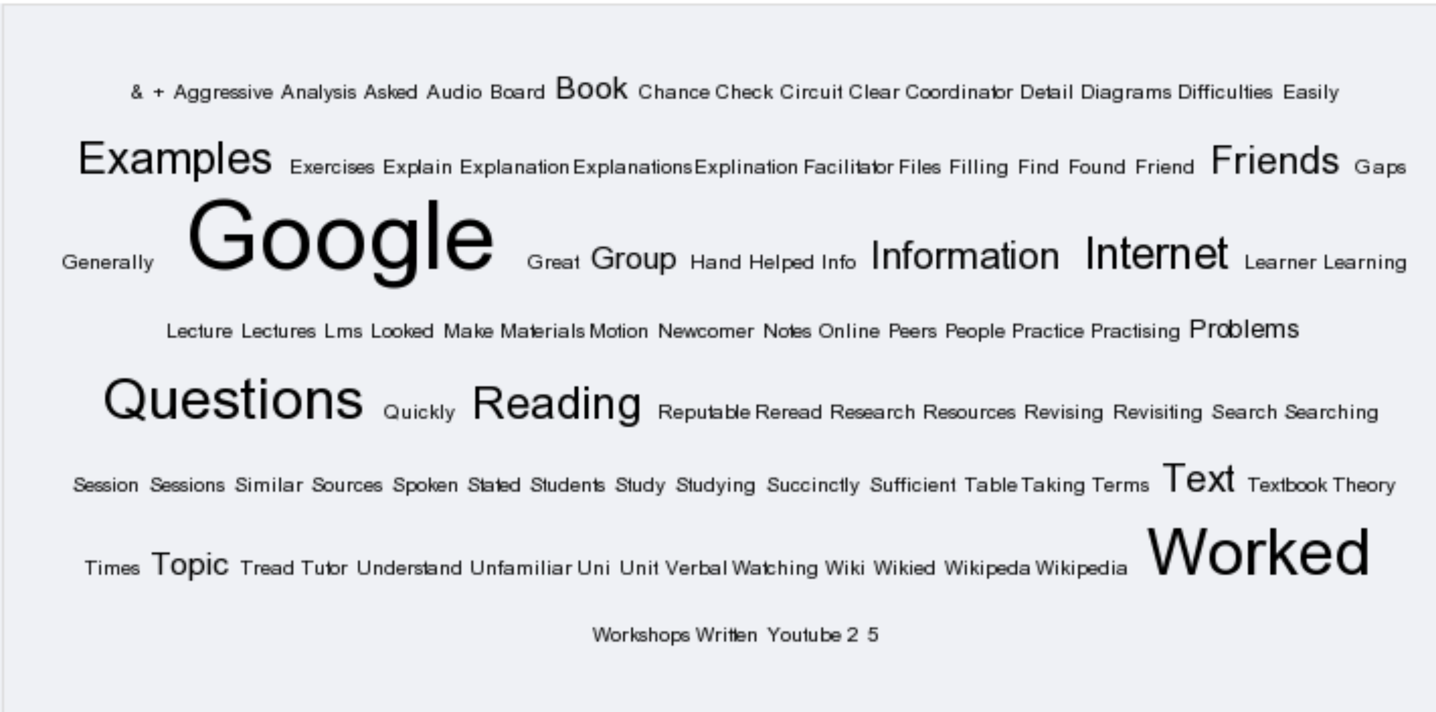

Figure 4.15 Word Cloud - what works Motion

 Asking Genius Friend Worked

> I googled the topic and quickly found many reputable sources that could easily and succinctly explain the topic in better detail in a way that I, as a newcomer, could understand. (ID Mot 70)

The most common responses to what *did not* work for students to learn something unclear in Motion were clustered around reading (11) and asking (7). While only one student responded that there was too much reading, the remaining survey respondents just indicated that reading did not work. Two clues were given in two student responses. One senior female student, when writing about what worked for her learning, noted:

> verbal/audio learner: need to find written/spoken explanations and worked examples. (ID Mot 67)

A senior female student who studied both Motion and Energy noted lectures worked for her as she had difficulty changing her learning style:

> hard to unlearn 10 years of a certain learning style! (ID E1).

Another senior male international student expressed difficulty in visualising the concepts:

> Imagined what's the topic is. This way can not help me achieve it. (ID Mot 63).

This suggests an unforeseen aspect to not providing lectures – a greater reliance on written materials. Conversations overheard while observing students in their classes indicated that students struggled to complete the amount of prereading, either because they did not want to read, preferring someone to verbally explain it to them (e.g., lecture), or their reading skills did not include the ability to read a large amount of information, distil the essential messages, summarise those messages, and incorporate those messages into a mental schema of the area being learnt – skills required of a graduate student, and not typically expected in undergraduate engineering students. 'Reading skills' also covers the responses of 3 students who wrote that 'self-learning' did not work for them.

The second area that did not work for students to learn something unclear in Motion is asking – a friend, the facilitator. Survey respondents noted that their facilitator would rush or give unclear explanations. In summary, a word cloud of the responses to this question is presented in Figure 4.16.

Figure 4.16 Word Cloud - Motion - doesn't work to learn

4.3.1.3 Energy

The most common responses to what worked for students to learn something unclear in Energy were using the internet (24), lecture (19) doing questions (18), and asking (17). Using the internet included using Google, Wikipedia, and YouTube including lectures from Khan Academy and other universities, although students noted lectures from other universities did not have the same content that was being covered in classes. A typical use of the internet was described by one senior male student:

> Looking at google for definitions and youtube for demonstrations. (ID E 56).

Lectures, lecture notes and worked examples in the lectures were seen as helpful. As described by a senior male student:

> I will read the lecture notes, then go through the practice questions, referring back to the lecture for formulae / explanations. If the lecture notes are not sufficient for me, I will Google for more resources or find a video tutorial on YouTube. (ID E 65).

The third most common response to what worked for students to learn something unclear in Energy was to work on solving questions. Six students noted the importance of solutions to see how the answers had been achieved and to verify their own understanding; five students highlighted the value of working with their group members as aiding their understanding.

The fourth most common response, asking, included asking a friend, the facilitator, and group members. In particular, one senior female student specified “Asking other who understand to help me understand” (ID E 49), and one senior male student stated “Asking genius friend worked.” (ID E 85). This intriguing second response provided a lens for analysis for the second part of this research.

A word cloud of the responses to this question is presented in Figure 4.17. In this word cloud, Google, YouTube, Wikipedia, and internet have not been aggregated, as in the summary in the above paragraphs.

Figure 4.17 Energy - Works to Learn

The most common responses to what *did not* work for students to learn something unclear in Energy were clustered around lectures and lecture notes (9), asking (5), and reading (4). The lectures and lecture notes were noted as not offering enough explanation or detail. Four students reported a lack of success in asking their facilitator, and one senior female students’ frustration with her group members was evident:

> Asking people in a group - often get wrong answer, or they have no interest in the unit so have not payed attention in class / prepared so are in no place to assist. (ID E 1).

Similar to the Motion unit, 4 students reported struggling with reading the notes, the text book and the self-learning aspect to the readings. In summary, a word cloud of the responses to this question is presented in Figure 4.18.

Figure 4.18 Energy - didn't work to learn

4.3.1.4 Working to understand an unclear topic – what worked / did not work - Summary

In the three units Materials, Motion, and Energy, students attempted a number of strategies to help them understand an unclear topic, the most common of which were to work through assignment and example questions, watch lectures and read through lecture notes, asking others, using the internet and reading. In all cases except for the internet and reading, these strategies both worked – and did not work. Doing questions worked, as long as there were solutions to provide a check that the process and understandings had been correctly applied. Lectures and lecture notes worked, as long as the lectures and lecture notes contained solutions to example questions, were complete, and, for internet lectures, covered the same material as in the unit. Asking someone worked, as long as it was someone who knew the material.

Most strategies were noted as both working and not working, but two strategies were noted as being particularly one sided – using the internet and reading. Using the internet was noted as strategy that worked in Motion and Energy, and not as a strategy that didn't work, although students noted it was time-consuming to find relevant material. In contrast, reading was noted in Motion as a strategy that did not work. Clues to why reading did not work are suggested in their comments and in the researcher's observations: students identified themselves as verbal or audio learners; students expected or were used to lectures; student's reading skills did not include the ability to read a large amount of information, distil the essential messages, summarise those messages, and incorporate those messages into a mental schema of the area being learnt; and students just gave up trying to read the background readings.

Without a lecture, there is a greater reliance on written materials. Reading and analysing engineering written materials requires skills that perhaps these engineering students do not yet have – or even desire. Perhaps with specialist attention to developing these required reading and analysing skills, the taste of success could help overcome a reluctance to effectively engage with the reading materials.

4.4 Interviews

Student activities observed in the classes (e.g., talking with group members, YouTube, asking friends) and questionnaire answers informed the questions developed for the interviews. After two introductory questions around a mind map of the unit's threshold concepts, the interview consisted of nine questions around what students found tricky, easy, spent their time on and what they did to learn something tricky. A copy of the interview protocol forms Appendix 2. Nine interviews with groups of 2 to 5 students were conducted, comprising 28 students (3 female, 25 male).

The group interviews used a semi-structured format, where an interview protocol formed the starting point for the interview without constraining student responses. This allowed unanticipated material to emerge and for the interviewee to shape the interview.

Asking Genius Friend Worked

The term' threshold concept' was not used in the interviews. Instead, concepts were described as tricky, hard or when something previously difficult to understand just 'clicked'.

4.4.1 Unit Mind map

At the start of the interview, all interviewees were shown a mind map of the unit's threshold concepts, asked whether the mind map made sense, and whether the mind map reflected their experience of the unit. All interviewees agreed that it did make sense. One international student noted that he had "learnt a lot" by looking at the mind map, while another noted that the size of the items of the mind map did not reflect the amount of time spent on the concept, unlike a word cloud.

4.4.2 Most time spent on ...

Interviewees were then asked to reflect on the unit thus far, and to identify what they seemed to spend most of their time on. Most interviewees pointed to specific threshold concepts on the mind map, but four meta-activities were identified: group activities, talking, waiting and working. 'Waiting' included waiting for equipment and waiting for instructions. 'Working' was more precisely working to understand the concepts rather than doing questions, and also included reading the text.

4.4.3 Tricky concepts

Interviewees were referred to the mind map and asked if any of the concepts were tricky. Answers ranged from the precise (bending moment diagrams, dimensional reasoning, phasors, reactive power, shear force diagrams, differential or integral form of equations), becoming more general (electrical, materials, solving problems only using a particular method, new terminology for non-English speaking background students), through to more abstract (brand new concepts, grasping intangible concepts, the first step, learning the materials). One Materials student noted that nothing was particularly tricky "Not when they explain it to you properly" (M1 M2).

4.4.4 Really easy concepts

After reflecting on what interviewees found tricky, interviewees were asked if any concepts were really easy. Answers again ranged from the specific (coordinate systems, resolving forces into components), though to the more general (circuits, motion, statics, thermodynamics, nothing, exercises and calculations). In addition, content that had been previously learnt was noted as being easy. This included the same or similar content being studied in a parallel unit, or had been studied in a previously passed unit.

Students who had previously learnt any of their unit's content in another unit were asked to reflect on their learning experiences in the other unit and offer their observations. One student commented on the positive impact of the emotional atmosphere created by a previous lecturer:

> he was very very enthusiastic and happy to help out students like help forums on line and he always replied, and things that like - kind of made it seem like he genuinely wanted us to do well, so helped us out. (E2 M2).

4.4.5 Initially easy, but tested hard

Interviewees were then asked whether there were some concepts that they thought were easy but on which they tested badly. Specific concepts included misjudging the difficulty of bending moment diagrams, shear force diagrams, differential or integral from of equations, method of sections, and Thevenin.

When asked about concepts on which they tested badly, some interviewees talked about tests and assessments in general. Some noted that they did not have tests, only quizzes. Others noted that the quizzes were multiple choice or designed so no calculations were required or were superficial.

Some interviewees expressed frustration with their tests, "impossible to succeed", assessment results "unpredictable", noting different interpretations given by the lecturer and the facilitator, assessment questions asking about content that was not covered in the lecture, with one student "they're trying to trick you". Students also expressed anxiety around upcoming assessments, noting unclear expectations around the final exam, and another noting a delay in posting assessment results and not knowing his current standing.

4.4.6 What worked to learn something tricky

After identifying tricky concepts, interviews were asked what really worked for them to learn those tricky concepts. Three strategies were identified – asking, doing and gathering.

'Asking' included asking students, the lecturer, a parent, the tutor, a genius friend, their group, older students, as well as explaining it to another student when he or she asks for help. 'Doing' encompassed working through examples and checking the solutions, practice, and repetition, both of examples and repeating the content in another unit. 'Gathering' reflected more passive activities such as watching YouTube lectures and explanations, rewatching lectures, reading through the lecture notes, reading a text book, reading the notes or text books of a more senior student or someone who had already completed the unit, watching someone else explaining the concept or working through a question. 'Gathering' involves accumulating enough *explanations* from different sources and at different levels of detail, or enough examples until it all falls into place.

Some students took the opportunity to preface their answers with what did not work to learn a tricky concept. Two main areas were disorganisation and disconnection – lectures, lecture notes or readings that were disorganised, did not reflect a logical flow, or were incomplete, and a disconnect between the material in classes and lectures and the text books, as well as a lack of consistency between content presented by the lecturer and the tutor. A third area was around asking the tutor/lecturer who did not seem to understand the question being asked.

> [Interviewer: Do you consider asking a lecturer or a tutor?]
> Not really here, at least lecturer - probably ask the lecturer – but in this thing, I made the experience that they didn't really get my questions most of the time, like where I was heading to. (E4 M1)
>
> Um, they actually – like – they know their stuff, like they're really smart and stuff, but it's really hard for them to answer our questions. (E4 F)

4.4.7 Strategies for understanding

The final question asked interviewees to recall a moment during the semester when they realized they had learned something new that was previously difficult to understand, when something just "clicked" for them, and to describe what led up to that moment, what it was like for them. The two strategies that worked were asking and doing.

The most common effective strategy involved asking a friend who knew the material: "It's good to have a smart friend." (E4 F) "There's always like this one really smart friend you can always like – ask" (E4 F). " I just ask my friends because I got a lot of friends who's very outstanding" (M4 F1). A smart friend not only knew the material, but was a safe person to ask. It also seems friends were able to explain the material at a more basic level than the tutor or lecturer, and understood the typical student pitfalls:

> I just think different explanations do it sometimes. I mean, like if listen to a lecturer once, it might not make sense, but then if I get a student perspective sometimes, that definitely helps all the time. <u>All the time</u>. I always need a student – like I always ask him. [points] Once I get like a student's view on it, they simplify it down <u>a lot</u> – if they understand it they can simplify it for you, and then that's all I – he's a genius friend. (M3 M4).

Asking a friend who knew the material to show the steps in solving a problem also led to a concept "clicking" for them:

> I just had no idea what I was doing, and then I was like – I'd check my notes – but that's not really helpful, because it doesn't actually put it into practice – and then I asked Dylan for some help – and then we actually walked through step by step for each joint and it made sense. (M3 M2)
>
> And when I do it, when I get a question, it's always hard to get the first step – to start off, to how to solve the problem. But once I see my friends do it, I go aah, so like – that's how you start it off, and then it just flows from there. So it is – you don't know how to start it off or– am I going in the right

direction like .. if I start from here and I go all the way down to there, like, am I doing something wrong in the middle or something? Once you know that, it just flows. (E4 M2)

For one student, one-on-one attention from his teacher (facilitator) was key to his understanding:

> There was one point, and then I was just – the teacher personally just helped me – probably spent 5 minutes on the board doing this equation – she's like – this is that, this is this, and it clicked.
>
> [Interviewer: Ok. So she drew something on the board, and she actually talked you through her thinking and her explaining it, so there was a visual as well as a verbal explanation]
>
> And it was one on one.
>
> [Interviewer: And it was one on one. OK.]
>
> Yea. And that just worked. (E3 M2).

For one group, an email from the lecturer, who "had a better explanation for it", (M1 M3) clarified their understanding.

The second most common strategy in understanding something that had been previously difficult to understand involved 'doing' – answering questions and problems around the concept, and persisting.

> For me, it's just keep doing examples. (E1 M1).
>
> Just doing, I reckon (E3 M1).
>
> at the start it's really hard to understand the concept, but when I go through several samples and do some specific questions, and then I found the solutions for solving that kind of question – it's like just – follow the steps, the first one is find the equation and do some calculations and then just follow the step and I can draw the diagram. (M4 M3)
>
> Well, I think a lot of exercises – it helps, you know, to understand the certain concept. Before this, when we started all the statics, I was terrible – I actually failed my first quiz – and then after that I improved, because - I think still understanding the concept actually helps you to do – you know – a big range of questions. I think that made me click. (M4 M2)

An international student emphasised that just the doing the exercises and getting a correct answer was not enough. To achieve understanding of a concept required asking questions along the way and understanding each step in solving a question:

> You cannot just do question. You cannot just understand concept without any like questions ask you how to do that one. It's really works. (M4 M4)

Other students also stated that both doing and asking helped a concept 'click' for them:

> I think doing questions definitely helps like if there's something that you don't get you can go back and ask people about what you're confused with, or you can get experience through doing problems, and you start to understand how these problems are meant to be solved just by looking at also other people doing the problems as well. You kind of get a better idea about how to solve them like. (E3 M1)
>
> I suppose when you kind of like first get exposed to it, it's like oh I'm not too sure, but then once you get through a few of the tute questions, and then talk about it with your group it becomes pretty straight forward. (M2 M4).
>
> I reckon group collaboration, like, groups doing this, this sort of stuff, working together, because sometimes I just have no idea. Someone else will say something, it will click, and then get the rest of it. (M2 M1).

One group noted that sometimes a concept had to be 'parked' until it was developed later in the unit, at which time the concept would 'click':

> I guess it's because we haven't learned the next topic. It's when we covered internal stresses kind of thing the thing actually clicked. So … it's like a later topic that wasn't explained earlier. So you need some kind of later topic to understand (the one at the beginning) that I had a query about. (M1 M1)

Finally, a group of international students raised two issues around understanding previously difficult concepts: language and visualisation. In their group, extra effort was required to understand the technical terminology used by the lecturer and facilitators, but once understood, the concepts being described by the words fell into place:

> Coz like I remember when the guy was talking about surface treatment - talking about how to (re)inforce the surface of metals - the strength – I really don't know what – because they have like annealing – like penning – and everything – so I really don't know what's all that about. He's like throwing everything at you. So that's why just like – read through the text book afterwards and find out all the words like – every words what he's talking about. And suddenly it's just like that (claps), you know. You skip everything. Everything just start to connect to – with everything – with other things and stuff, (M4 F1)

The second issue that contributed to understanding previously difficult concepts was visualising abstract or previously unencountered concepts. Some concepts were easier to visualise than others. Concepts in Statics such as force diagrams were considered easy because the structure being analysed could be easily modelled or represented, and forces, beams and steel were concepts that had been previously encountered. In contrast, the internal structure of materials was reported as being difficult to visualise as there were no analogues in everyday life that could form the start of a mental model:

> it's all in like microstructures stuff – so something like human eye can't see- so it's not something you're seeing and like – hearing or listening everyday – so that's making it so hard and unclear to us. (M4 F1).

Difficulty in visualising abstract concepts was also noted by an electrical student. Compared to the thermodynamics part of the unit:

> It's harder to grasp a concept in electrical. (E4 F).

4.4.8 Expectations

Interviewees talked about their expectations. Students expected the content at university to be hard, expected that learning the underlying concepts was more important than just being to answer questions, acknowledged that the lecturer had a great deal of content to cover in the lecture, and students expected to follow up a lecture with reading and study of their own. Students were not expecting to be 'spoon fed' – they fully expected to work at their study, but did expect the university to provide resources and make them available to help with that study.

A second source of expectations was around the published lesson plans. An expectation had been set that the two hour interactive session would follow the lesson plan, but it rarely had been.

4.4.9 Summary

The nine interviews with 28 students provided details of their experiences around threshold concepts that were consistent with the survey data, but with key aspects of their learning experiences highlighted. The next chapter draws together the data from this chapter and summarises the themes that emerged and offers recommendations.

5 Discussion and Recommendations

The aim of this research was to investigate how students experienced the identified threshold concepts in three engineering foundation units, Materials, Motion, and Energy, within the developed pedagogy. The research used observations, a survey and interviews to explore the students' experiences. Five major themes emerged from the data.

5.1 "Nothing is hard as long as it is explained well"

Threshold concepts are those concepts that students find troublesome, are critical to students' progress and are transformative for students (Meyer & Land, 2003). However, students indicated that only a few threshold concepts were indeed troublesome and transformative. Those that were, such as *Phasors* and *Reactive Power*, were troublesome in part as the students had difficulty visualising abstract concepts that were not part of every day life.

When students sought to understand a difficult concept, they used three strategies – asking, doing, and gathering. Gathering involved finding multiple explanations of the concept. These explanations could be found on YouTube, on-line lectures, text books, or by asking friends, group members, facilitators, lecturers, or more senior students. Some explanations were cursory, while others needed to go back to basics. A preference for spoken, rather than written, explanations was noted. Once an appropriate explanation was found and understood, a concept was seen as no longer difficult.

Recommendations: Visualisations

- *Build a bank of explanations that students have found useful (e.g., Khan Academy)*
- *Facilitators and lecturers to find visualisations for concepts that students find difficult.*

5.2 "Doing questions"

When students sought to understand a difficult concept, they used three strategies – asking, doing, and gathering. Doing encompassed working through examples and checking the solutions, practice, and repetition. Doing (answering questions) was the student's way of determining if they understood a concept. If they answered the question correctly, they had applied the concept correctly and thus understood the concept.

A focus on answering questions correctly is not surprising. Teachers in compulsory schooling use correctly answered questions in tests and exams as measures of understanding. Students soon adopt the same perception.

Students valued questions with answers or solutions. Those with older friends would attempt the questions in the notes and textbooks of their older friends.

Recommendations: Doing

- *Build a bank of questions with solutions, or sources of questions.*
- *Encourage students to recognise that even through they have answered a question 'correctly', that does not mean that they understand the underlying concepts.*
- *Find other ways for students to apply their understanding of a concept beyond just the correct answer to a question.*

5.3 "Reading with no other help"

The developed pedagogies of the three foundation engineering units differed slightly – one presented lectures, the second offered a weekly briefing session and the third unit's learning activities were focussed around the 2 hour information sessions without lectures. In the latter two units, students were required to complete set readings before their information sessions.

This greater reliance on written materials highlighted an unforeseen weakness in student learning skills - the ability to read a large amount of information, distil the essential messages, summarise those messages, and incorporate those messages into a mental schema of the area being learnt.

Some students commented that their learning styles were audio / visual, and they did not prefer to learn by reading. While acknowledging these learning preferences, the reality of engineering practice is that technical reports, design reports, maintenance reports, proposals, budgets documents and contract materials must be read and written. The design of a product or process requires reading Standards, reports, and technical manuals, and distilling the relevant content, typically in short timeframes. The ability to read and process large amounts of technical information is even more important for those intending to undertake graduate studies.

Recommendation: Reading

- *Provide explicit training in how to read and process large amount of written materials*
- *Highlight to students that large amounts of technical reading and 'self-learning' is still part of engineering practice, regardless of preferred learning style.*

5.4 "Asking genius friend worked"

The most common and most effective way reported by students to help them understand a difficult concept was to ask someone who knew the concept, but a hierarchy emerged – students were unlikely to ask a lecturer, slightly more likely to ask a facilitator, but were most likely to ask a peer, and in particular, a "genius friend". The "genius friend" was the preferred 'goto' person for males and females, first year students and more senior students, local and international students. The "genius friend" may not see himself or herself as a genius – they just need to be someone who is ahead of the others, and ideally appreciates the pitfalls in trying to understand a concept.

Recommendations: Asking

Recognise the asking hierarchy (lecturer (least likely) – facilitator (sometimes) - genius friend (most likely)):

Lecturers and Unit Coordinators:

- *When a student does ask for assistance, recognise this as a rare learning opportunity. They have most likely exhausted other avenues.*
- *Reconsider the practice of 'Consultation Hours'. If the lecturer is the helper of last resort, then offer the help when required. Perhaps Consultation Hours could be replaced with appointments made by email.*
- *Don't be surprised to have to go back to basic principles. Try to understand the question from the student's viewpoint.*

Facilitators:

- *When a student does ask for assistance, he or she is approaching you after having already tried other approaches.*
- *Don't be surprised to have to go back to basic principles. Try to understand the question from the student's viewpoint.*
- *Find ways to help the student visualise abstract concepts. Use metaphors to allow students to draw connections with real life examples.*
- *If students are chatting in a class, more likely than not they are discussing their work.*
- *Sometimes is a student is struggling with a concept, the class is as well. Be prepared to call the class to silence to offer an explanation or your working out to the whole class.*

5.5 All quiet on the international front

One of the aims of this research was to explore the differences in the experiences of international students and local students. However, international students were found to answer the minimum number of questions in the survey, and not write anything in the open-ended questions. If something was written, it was not critical and not negative.

Some international students may have experienced schooling in educational cultures where teachers and lecturers are not criticised. Others may see themselves as guests at this university and as guests in this country, and could be reluctant to criticise their hosts in any way. A comparison between the experiences of local and international students around threshold concepts was thus not as rich as hoped. However, the five international students interviewed as a group provided rich detail of their learning experiences. In particular, they highlighted their willingness to use the lecture as just a starting point for further study, the key role of their network of smart friends, and the extra effort required to understand the engineering technical terms.

Recommendation: International

- *Recognise the vulnerability some international students may experience.*
- *Take the effort to introduce technical and unfamiliar terminology.*

5.6 Limitations

One limitation of the research involved terminology – the aim was to understand student experiences of threshold concepts without using the term ‘threshold concept’. The approach taken was to describe threshold concepts as ‘tricky’, and acknowledged as difficult to understand. Those being interviewed were presented with a mind map of the threshold concepts, which helped narrow student responses more accurately. Although the threshold concepts were described in the questionnaire and in the interviews, students may still have based their responses on difficult concepts in general rather than threshold concepts.

A second limitation involves the timing of the research. Students reported finding most threshold concepts easy, but this was during semester, before the students had sat the final exam. An examination of exam papers would reveal patterns in student responses that could highlight which concepts students did indeed find difficult. Follow up interviews with the interviewed students after the exam would reveal if students had changed their minds about the difficulty of concepts previously considered hard or easy.

5.7 Implications for further research

When students experienced a difficult or threshold concept, three strategies were used to move past the difficulty: asking, doing and gathering. One direction for further research would be to determine what makes a good answer, a good explanation. For example, is a reference to real life experience required?

A second direction for further research would be to explore other ways to assess student understanding of a concept apart from correct answers to questions.

6 Conclusion

The aim of this research was to investigate how students experienced the threshold concepts of three engineering foundation units within the developed pedagogy. Student experiences were noted during class observations, captured in a survey and revealed more intensely in interviews of students studying the three engineering foundation units Materials, Motion, and Energy during Semester 2, 2012.

When encountering a threshold concept, students adopted three strategies: asking, doing and gathering. 'Asking' included asking students, the lecturer, a parent, the tutor, a genius friend, their group, older students, as well as explaining it to another student when he or she asks for help. 'Doing' encompassed working through examples and checking the solutions, practice, and repetition. 'Gathering' reflected more passive activities such as watching YouTube lectures and explanations, rewatching lectures, reading through the lecture notes, reading a text book, reading the notes or text books of a more senior student or someone who had already completed the unit, watching someone else explaining the concept or working through a question. 'Gathering' involved accumulating enough *explanations* from different sources and at different levels of detail, or enough examples until it all fell into place. Most students used a combination of the three strategies.

When 'asking' someone to help them learn a threshold concept, a hierarchy emerged, The most common person to ask was a peer, and in particular, a "genius friend", someone who knew the concept and was safe to ask. Less commonly, the facilitator was approached. Finally, the lecturer was rarely asked.

Most students stated they did not find most of the threshold concepts difficult. After asking, doing and gathering, students felt they understood a concept and it was no longer seen as difficult.

Students expressed reluctance to engage with pre-reading. This highlighted a lack of appropriate reading skills in the students, which required the ability to read a large amount of information, distil the essential messages, summarise those messages, and incorporate those messages into a mental schema of the area being learnt.

Finally, international students were reluctant to comment negatively on any aspect of their learning experiences.

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Appendix 1 Human Research Ethics Approval

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence

Research Ethics and Biosafety Office
Research Services
Phone: +61 8 6488 1610
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email: hreo-research@uwa.edu.au
MBDP: M459

Our Ref: RA/4/1/5500

16 July 2012

Winthrop Professor James Trevelyan
Mechanical & Chemical Engineering (School of)
MBDP: M050

Dear Professor Trevelyan

HUMAN RESEARCH ETHICS APPROVAL - THE UNIVERSITY OF WESTERN AUSTRALIA

Students' Experiences of Threshold Concepts

Student(s):

Ethics approval for the above project has been granted in accordance with the requirements of the *National Statement on Ethical Conduct in Human Research* (National Statement) and the policies and procedures of The University of Western Australia. Please note that the period of ethics approval for this project is five (5) years from the date of this notification. However, ethics approval is conditional upon the submission of satisfactory progress reports by the designated renewal date. Therefore inital approval has been granted from 16 July 2012 to 01 July 2013.

You are reminded of the following requirements:

1. The application and all supporting documentation form the basis of the ethics approval and you must not depart from the research protocol that has been approved.
2. The Human Research Ethics Office must be approached for approval in advance for any requested amendments to the approved research protocol.
3. The Chief Investigator is required to report immediately to the Human Research Ethics Office any adverse or unexpected event or any other event that may impact on the ethics approval for the project.
4. The Chief Investigator must inform the Human Research Ethics Office as soon as practicable if a research project is discontinued before the expected date of completion, providing reasons.

Any conditions of ethics approval that have been imposed are listed below:

Special Conditions

None specified

The University of Western Australia is bound by the National Statement to monitor the progress of all approved projects until completion to ensure continued compliance with ethical standards and requirements.

The Human Research Ethics Office will forward a request for a Progress Report approximately 60 days before the due date. A further reminder will be forwarded approximately 30 days before the due date.

If your progress report is not received by the due date for renewal of ethics approval, **your ethics approval will expire**, requiring that all research activities involving human participants cease immediately.

If you have any queries please do not hesitate to contact the Human Research Ethics Office (HREO) at hreo-research@uwa.edu.au or on (08) 6488 3703.

Please ensure that you quote the file reference – RA/4/1/5500 – and the associated project title in all future correspondence.

Yours sincerely

Peter Johnstone
Manager

Appendix 2 Interview Protocol

Interview

Student Experiences of Threshold Concepts: Engineering

Information: About this Survey

We would like to understand more about *how* you are learning in this unit.

The results of this survey will help us improve the course next semester.

Your response is private, confidential and anonymous.

This study has been approved by UWA Human Research and Ethics Committee, RA/4/1/5500.

.

This unit is designed around a number of tricky concepts, understandings and abilities. (Show mind map of the unit:)

Does the picture make sense? When you look at it, does it reflect your experience of the unit?

Thinking back on the unit, what did you seem to spend most of your time on?

Were any of these concepts tricky?
Were any really easy?
Were there some that you thought were easy but you did badly on in the tests?

When you found something tricky, what really worked?

Can you remember a moment during the semester when you realized you had learned something new that was previously difficult to understand, when something just "clicked" for you.
Can you tell me what led up to that moment, what it was like for you?"

Any other comments or suggestions:

Thank you for participating in our study.

Appendix 3 Questionnaire - Materials

Survey

Student Experiences of Threshold Concepts: Engineering

Information: About this Survey

We would like to understand more about how you are learning in this course. For that, we need your help. You don't have to take part, and it won't affect your grades or anything else.

The results of this survey will help us improve the course next semester.

Your response is private, confidential and anonymous.

This survey is in 5 parts:

A. About You and Your Study
B. Your Preparation for the Engineering Foundation Classes
C. In Class and After
D. Your Experience of Learning Threshold Concepts and Understandings
E. Final Comments

This study has been approved by UWA Human Research and Ethics Committee, RA/4/1/5500.

A. About You and Your Study

1. Are you studying more than one ENSC unit this Semester? Yes ❑ No ❑

2. Have you previously completed another ENSC unit Yes ❑ No ❑
If so, please select the units you have completed below:

Global Challenges (ENSC1001)	❑	1
Materials (ENSC1002)	❑	2
Motion (ENSC2001)	❑	3
Energy (ENSC2002)	❑	4

3. What is your other field of study or major?(e.g., Accounting, Arts, Business, Science, etc)
……………………………………………………

4. Gender: Female ❑ Male ❑

5. Is this your first year at university? Yes ❑ No ❑

6. Did you complete your high school in Western Australia? Yes ❑ No ❑
If not, State/country where completed:
……………………………………………………...

B. Your Preparation for the Engineering Foundation Classes

In this unit, students are required to complete a number of specified pre-class activities in preparation for their in-class activities. These classes are (i) Information Sessions (IS) and (ii) Workshops or Practicals.

1. *Reflecting* on your preparations so far,

	(hours) 0	2	4	6
Typically, how many hours a week do you spend *preparing* for the IS?				

2. In preparing for this week's classes, I ...*(select as many as apply)*

Attended or watched the lectures	❑	0	Went through the lecture notes	❑	9
Accessed LMS	❑	1	Worked through the practice questions	❑	5
Read all the background readings	❑	2	Studied with people in my group	❑	6
Looked up any *on-line* links referred to in the background readings	❑	3	Studied with my friends	❑	7
Looked up *other* material referred to in the background readings	❑	4	Other (please describe)	❑	8

3. Was there something in this week's Information Session that *wasn't clear* to you? Yes ❑ No ❑
If yes, what wasn't clear? ……………………………………………………………………………………………
To help my understanding, I …… *(select as many as apply) (more over the page)*

Watched the lecture on this topic – from *this* university	❑ 1	Watched a lecture on this topic – from *another* university	❑ 8
Posted or reviewed questions on a forum	❑ 2	Asked someone else not in my group and not a friend	❑ 9
Found a video on youtube	❑ 3	Asked my group facilitator	❑ 10
Looked up Wikipedia	❑ 4	Consulted the unit coordinator	❑ 11
Googled for the information	❑ 5	Looked up a text book	❑ 12
Asked my friends	❑ 6	Looked up another book	❑ 13
Asked people in my group	❑ 7	Other (please describe)	❑ 14

4. *Reflecting* on what you did to learn an unclear topic, what did you find worked very well for you?

What did not work?

C. In Class and After

1. When thinking about *your learning in class*, how important are each of the following aspects:

	Very Important ⟵				⟶ Not at all Important
Working with my group members	5	4	3	2	1
The worked examples on the boards by the facilitator	5	4	3	2	1
The worked examples on the boards by other students	5	4	3	2	1
The explanations of my facilitator	5	4	3	2	1
Having completed the pre-reading	5	4	3	2	1
Having completed the required exercises	5	4	3	2	1
Other (please describe)					

2. *Reflecting* on your work after class so far,

	(hours)	0	2	4	6
Typically, how many hours a week after the class do you spend consolidating your knowledge and completing homework?					

D. Your Experience of Learning Threshold Concepts and Understandings - Materials

This unit is designed around a number of tricky concepts, understandings and abilities. Please indicate how you felt about the level of difficulty, the amount of time and your level of confidence around these:

1. Simplifying a physical system for analysis by choosing an appropriate *model* (e.g., a mathematical model)

	Really hard	Not hard at all
• How hard was this concept?		
	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		
	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

2. All systems and their parts tend to equilibrium

	Really hard	Not hard at all
• How hard was this concept?		
	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		
	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

3. The relationship between stress and strain

	Really hard	Not hard at all
• How hard was this concept?		
	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		
	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

4. *Self-driven Learning.* e.g., there are different ways to learn and from different sources;

	Very important	Not at all important
• How **important** do you believe *self-driven learning* is to successful engineering practice?		
	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *self-drive learning.*		
	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *self-driven learner?*		

5. *Communication* – two-way, effective communication in many forms is critical to engineering practice.

	Very important	Not at all important
• How **important** do you believe *communication* is to successful engineering practice?		
	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *communicate.*		
	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *communicator?*		

6. *Leadership* – Engineers spend much of their time coordinating the work of people over whom they might have no direct authority.

	Very important	Not at all important
• How **important** do you believe *leadership* is to successful engineering practice?		
	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *be a leader.*		
	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *leader?*		

7. *Teamwork* – Engineers spend much of their time working with others;. teams can achieve more than the sum of the individuals working alone

	Very important	Not at all important
• How **important** do you believe *teamwork* is to successful engineering practice?		
	Strongly Agree	**Strongly Disagree**
• Since the start of this unit, I have gained a greater **ability** to *be a team player.*		
	Very confident	**Not confident at all**
• How confident do you feel about your abilities to be an **effective** *team player?*		

E. Final Comments

Any other comments or suggestions:

Thank you for participating in our study.

Appendix 4 Questionnaire - Motion

Survey

Student Experiences of Threshold Concepts: Engineering

Information: About this Survey

We would like to understand more about how you are learning in this course. For that, we need your help. You don't have to take part, and it won't affect your grades or anything else.

The results of this survey will help us improve the course next semester.

Your response is private, confidential and anonymous.

This survey is in 5 parts:

A. About You and Your Study
B. Your Preparation for the Engineering Foundation Classes
C. In Class and After
D. Your Experience of Learning Threshold Concepts and Understandings
E. Final Comments

This study has been approved by UWA Human Research and Ethics Committee, RA/4/1/5500.

A. About You and Your Study

1. Are you studying more than one ENSC unit this Semester? Yes ❑ No ❑
2. Have you previously completed another ENSC unit Yes ❑ No ❑
   If so, please select the units you have completed below:

Global Challenges (ENSC1001)	❑ [1]
Materials (ENSC1002)	❑ [2]
Motion (ENSC2001)	❑ [3]
Energy (ENSC2002)	❑ [4]

3. What is your other field of study or major?(e.g., Accounting, Arts, Business, Science, etc)
   ……………………………………………………
4. Gender: Female ❑ Male ❑
5. Is this your first year at university? Yes ❑ No ❑
6. Did you complete your high school in Western Australia? Yes ❑ No ❑
   If not, State/country where completed:
   ……………………………………………………….

B. Your Preparation for the Engineering Foundation Classes

In this unit, students are required to complete a number of specified pre-class activities in preparation for their in-class activities. These classes are (i) Information Sessions (IS) and (ii) Workshops or Practicals.

1. *Reflecting* on your preparations so far,

	(hours) 0 2 4 6
Typically, how many hours a week do you spend *preparing* for the IS?	

2. In preparing for this week's class, I …*(select as many as apply)*

Accessed LMS	❑ [1]	Worked through the practice questions	❑ [5]
Read all the background readings	❑ [2]	Studied with people in my group	❑ [6]
Looked up any *on-line* links referred to in the background readings	❑ [3]	Studied with my friends	❑ [7]
Looked up *other* material referred to in the background readings	❑ [4]	Other (please describe)	❑ [8]

3. Was there something in this week's Information Session that *wasn't clear* to you? Yes ❑ No ❑
If yes, what wasn't clear? ……………………………………………………………………………………
To help my understanding, I …… *(select as many as apply) (more over the page)*

Watched a lecture on this topic – from *this* university	❑ 1	Watched a lecture on this topic – from *another* university	❑ 8
Posted or reviewed questions on a forum	❑ 2	Asked someone else not in my group and not a friend	❑ 9
Found a video on youtube	❑ 3	Asked my group facilitator	❑ 10
Looked up Wikipedia	❑ 4	Consulted the unit coordinator	❑ 11
Googled for the information	❑ 5	Looked up a text book	❑ 12
Asked my friends	❑ 6	Looked up another book	❑ 13
Asked people in my group	❑ 7	Other (please describe)	❑ 14

4. *Reflecting* on what you did to learn an unclear topic, what did you find worked very well for you? What did not work?
Worked:

Did not work:

C. In Class and After

1. When thinking about *your learning in class*, how important are each of the following aspects:

	Very Important				Not at all Important
Working with my group members	5	4	3	2	1
The worked examples on the boards by the facilitator	5	4	3	2	1
The worked examples on the boards by other students	5	4	3	2	1
The explanations of my facilitator	5	4	3	2	1
Having completed the pre-reading	5	4	3	2	1
Having completed the required exercises	5	4	3	2	1
Other (please describe)					

2. *Reflecting* on your work after class so far,

	(hours)	0	2	4	6
Typically, how many hours a week after the class do you spend consolidating your knowledge and completing homework?					

D. Your Experience of Learning Threshold Concepts and Understandings - Motion

This unit is designed around a number of tricky concepts, understandings and abilities. Please indicate how you felt about the level of difficulty, the amount of time and your level of confidence around these:

1. Identifying and defining the *system* (noting system boundaries) is a useful starting point in analysing and simplifying a system

	Really hard	Not hard at all
• How hard was this concept?		
	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		
	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

2. In solving a circuit problem (identifying the voltages, currents, etc), the circuit can be simplified for analysis by choosing an appropriate circuit *model*.

	Really hard	Not hard at all
• How hard was this concept?		

	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		

	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

3. Conservations laws can be used to analyse a system. For example, conservation laws for charge and energy can be used to analyse electrical circuits.

	Really hard	Not hard at all
• How hard was this concept?		

	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		

	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

4. *Self-driven Learning.* e.g., there are different ways to learn and from different sources;

	Very important	Not at all important
• How **important** do you believe *self-driven learning* is to successful engineering practice?		

	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *self-drive learning.*		

	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *self-driven learner?*		

5. *Communication* – two-way, effective communication in many forms is critical to engineering practice.

	Very important	Not at all important
• How **important** do you believe *communication* is to successful engineering practice?		

	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *communicate.*		

	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *communicator?*		

6. *Leadership* – Engineers spend much of their time coordinating the work of people over whom they might have no direct authority.

	Very important	Not at all important
• How **important** do you believe *leadership* is to successful engineering practice?		

	Strongly Agree	Strongly Disagree
• Since the start of this unit, I have gained a greater **ability** to *be a leader.*		

	Very confident	Not confident at all
• How confident do you feel about your abilities to be an **effective** *leader?*		

7. *Teamwork* – Engineers spend much of their time working with others;. teams can achieve more than the sum of the individuals working alone

	Very important	Not at all important
• How **important** do you believe *teamwork* is to successful engineering practice?		
	Strongly Agree	**Strongly Disagree**
• Since the start of this unit, I have gained a greater **ability** to *be a team player.*		
	Very confident	**Not confident at all**
• How confident do you feel about your abilities to be an **effective** *team player?*		

E. Final Comments

Any other comments or suggestions:

Thank you for participating in our study.

Appendix 5 Questionnaire - Energy

Survey

Student Experiences of Threshold Concepts: Engineering

Information: About this Survey

We would like to understand more about how you are learning in this course. For that, we need your help. You don't have to take part, and it won't affect your grades or anything else.

The results of this survey will help us improve the course next semester.

Your response is private, confidential and anonymous.

This survey is in 5 parts:

A. About You and Your Study
B. Your Preparation for the Engineering Foundation Classes
C. In Class and After
D. Your Experience of Learning Threshold Concepts and Understandings
E. Final Comments

This study has been approved by UWA Human Research and Ethics Committee, RA/4/1/5500.

A. About You and Your Study

1. Are you studying more than one ENSC unit this Semester? Yes ❑ No ❑
2. Have you previously completed another ENSC unit Yes ❑ No ❑
   If so, please select the units you have completed below:

Global Challenges (ENSC1001)	❑ [1]
Materials (ENSC1002)	❑ [2]
Motion (ENSC2001)	❑ [3]
Energy (ENSC2002)	❑ [4]

3. What is your other field of study or major?(e.g., Accounting, Arts, Business, Science, etc)
   ……………………………….……...……….……
4. Gender: Female ❑ Male ❑
5. Is this your first year at university? Yes ❑ No ❑
6. Did you complete your high school in Western Australia? Yes ❑ No ❑
   If not, State/country where completed:
   ………………………………………………….…...

B. Your Preparation for the Engineering Foundation Classes

In this unit, students are required to complete a number of specified pre-class activities in preparation for their in-class activities. These classes are (i) Information Sessions (IS) and (ii) Workshops or Practicals.

1. *Reflecting* on your preparations so far,

	(hours) 0 2 4 6
Typically, how many hours a week do you spend *preparing* for the IS?	

2. In preparing for this week's class, I ...*(select as many as apply)*

Accessed LMS	❑ [1]	Worked through the practice questions	❑ [5]
Read all the background readings	❑ [2]	Studied with people in my group	❑ [6]
Looked up any *on-line* links referred to in the background readings	❑ [3]	Studied with my friends	❑ [7]
Looked up *other* material referred to in the background readings	❑ [4]	Other (please describe)	❑ [8]

3. Was there something in this week's Information Session that *wasn't clear* to you? Yes ❑ No ❑
If yes, what wasn't clear? ……………………………………………………………………………………
To help my understanding, I …… *(select as many as apply) (more over the page)*

Watched a lecture on this topic – from *this* university	❑ 1	Watched a lecture on this topic – from *another* university	❑ 8
Posted or reviewed questions on a forum	❑ 2	Asked someone else not in my group and not a friend	❑ 9
Found a video on youtube	❑ 3	Asked my group facilitator	❑ 10
Looked up Wikipedia	❑ 4	Consulted the unit coordinator	❑ 11
Googled for the information	❑ 5	Looked up a text book	❑ 12
Asked my friends	❑ 6	Looked up another book	❑ 13
Asked people in my group	❑ 7	Other (please describe)	❑ 14

4. *Reflecting* on what you did to learn an unclear topic, what did you find worked very well for you? What did not work?

C. In Class and After

1. When thinking about *your learning in class*, how important are each of the following aspects:

	Very Important ⟷				Not at all Important
Working with my group members	5	4	3	2	1
The worked examples on the boards by the facilitator	5	4	3	2	1
The worked examples on the boards by other students	5	4	3	2	1
The explanations of my facilitator	5	4	3	2	1
Having completed the pre-reading	5	4	3	2	1
Having completed the required exercises	5	4	3	2	1
Other (please describe)					

2. *Reflecting* on your work after class so far,

	(hours)	0	2	4	6
Typically, how many hours a week after the class do you spend consolidating your knowledge and completing homework?					

D. Your Experience of Learning Threshold Concepts and Understandings - Energy

This unit is designed around a number of tricky concepts, understandings and abilities. Please indicate how you felt about the level of difficulty, the amount of time and your level of confidence around these:

1. In solving a circuit problem (identifying the voltages, currents, etc), the circuit can be simplified for analysis by choosing an appropriate circuit *model* (Thevenin, Norton).

	Really hard	Not hard at all
• How hard was this concept?		
	Need More Time	Prefer Less Time
• Was enough time allocated in this unit to enable you to learn this concept?		
	Very confident	Not confident at all
• How confident do you feel about *applying* this concept to the material covered so far in this unit?		

2. In solving a circuit problem (identifying the voltages, currents, etc), there is a *standard language* for *drawing* and *representing* the circuit. Redrawing the circuit by rearranging the nodes and branches makes circuit analysis easier.

	Really hard — Not hard at all / Need More Time — Prefer Less Time / Very confident — Not confident at all
• How hard was this concept?	Really hard ⊢—+—⊣ Not hard at all
• Was enough time allocated in this unit to enable you to learn this concept?	Need More Time ⊢—+—⊣ Prefer Less Time
• How confident do you feel about *applying* this concept to the material covered so far in this unit?	Very confident ⊢—+—⊣ Not confident at all

3. Taking any circuit and drawing a dividing line across two points (Identifying and defining the *system*), viewing / replacing one side of the circuit with its Thevenin/Norton equivalent and considering the other side as the "load".

• How hard was this concept?	Really hard ⊢—+—⊣ Not hard at all
• Was enough time allocated in this unit to enable you to learn this concept?	Need More Time ⊢—+—⊣ Prefer Less Time
• How confident do you feel about *applying* this concept to the material covered so far in this unit?	Very confident ⊢—+—⊣ Not confident at all

4. Phasors for analysis of AC circuits

• How hard was this concept?	Really hard ⊢—+—⊣ Not hard at all
• Was enough time allocated in this unit to enable you to learn this concept?	Need More Time ⊢—+—⊣ Prefer Less Time
• How confident do you feel about *applying* this concept to the material covered so far in this unit?	Very confident ⊢—+—⊣ Not confident at all

5. Reactive Power: vs Real Power and Complex Power

• How hard was this concept?	Really hard ⊢—+—⊣ Not hard at all
• Was enough time allocated in this unit to enable you to learn this concept?	Need More Time ⊢—+—⊣ Prefer Less Time
• How confident do you feel about *applying* this concept to the material covered so far in this unit?	Very confident ⊢—+—⊣ Not confident at all

6. *Self-driven Learning.* e.g., there are different ways to learn and from different sources;

• How **important** do you believe *self-driven learning* is to successful engineering practice?	Very important ⊢—+—⊣ Not at all important
• Since the start of this unit, I have gained a greater **ability** to *self-drive learning*.	Strongly Agree ⊢—+—⊣ Strongly Disagree
• How confident do you feel about your abilities to be an **effective** *self-driven learner?*	Very confident ⊢—+—⊣ Not confident at all

7. *Communication* – two-way, effective communication in many forms is critical to engineering practice.

	Very important	Not at all important
• How **important** do you believe *communication* is to successful engineering practice?		
	Strongly Agree	**Strongly Disagree**
• Since the start of this unit, I have gained a greater **ability** to *communicate.*		
	Very confident	**Not confident at all**
• How confident do you feel about your abilities to be an **effective** *communicator?*		

8. *Leadership* – Engineers spend much of their time coordinating the work of people over whom they might have no direct authority.

	Very important	Not at all important
• How **important** do you believe *leadership* is to successful engineering practice?		
	Strongly Agree	**Strongly Disagree**
• Since the start of this unit, I have gained a greater **ability** to *be a leader.*		
	Very confident	**Not confident at all**
• How confident do you feel about your abilities to be an **effective** *leader?*		

9. *Teamwork* – Engineers spend much of their time working with others;. teams can achieve more than the sum of the individuals working alone

	Very important	Not at all important
• How **important** do you believe *teamwork* is to successful engineering practice?		
	Strongly Agree	**Strongly Disagree**
• Since the start of this unit, I have gained a greater **ability** to *be a team player.*		
	Very confident	**Not confident at all**
• How confident do you feel about your abilities to be an **effective** *team player?*		

E. Final Comments

Any other comments or suggestions:

Thank you for participating in our study.

Appendix 6 Questionnaire Notes

Survey Notes

Student Experiences of Threshold Concepts: Engineering

Thank you for taking the time to run this survey with Engineering Foundation students.

1. **Timing**: 5 – 10 minutes. The survey typically takes students about 5 minutes. Allow an additional 5 minutes for those who would like to write detailed comments.
2. **Encourage** students to complete the survey. While students are free to choose to *not* participate, encourage them to complete it anyway - It is an opportunity for the students to reflect on how they are doing in their studies so far. They may also choose to complete the survey, but not hand it in.
3. **Quicker answers, rather than dwelling**: Most questions don't require too much thinking about to answer. Usually, your first response is the accurate one.
4. **Student focus**: The questions focus solely on what the students are doing to learn in this unit.
5. **Survey summary**: Some students may be interested in the results of the survey. A summary of the results will be available to interested staff and students when the analysis is completed.

** Please let the students know of one amendment to the survey: **

6. **Part B Question 4:** The question asked what students found worked and what students found didn't work. If students do write something for this question, could they please clearly indicate if it worked or didn't work. For example:

   Reflecting on what you did to learn an unclear topic, what did you find worked very well for you? What did not work?

   Worked: watching the lecture online; doing the practice questions;

   Didn't work: the explanations in the text book.

The information for survey participants given at the beginning of the survey is copied in the box below.

Information: About this Survey

We would like to understand more about how you are learning in this course. For that, we need your help. You don't have to take part, and it won't affect your grades or anything else.

The results of this survey will help us improve the course next semester.

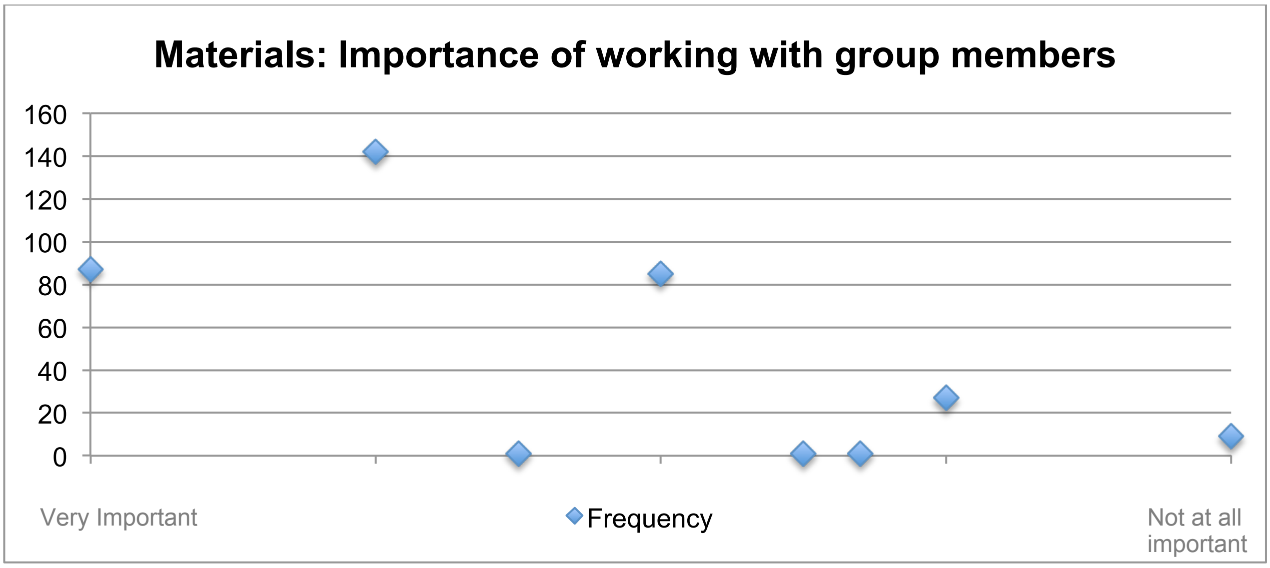
Your response is private, confidential and anonymous.

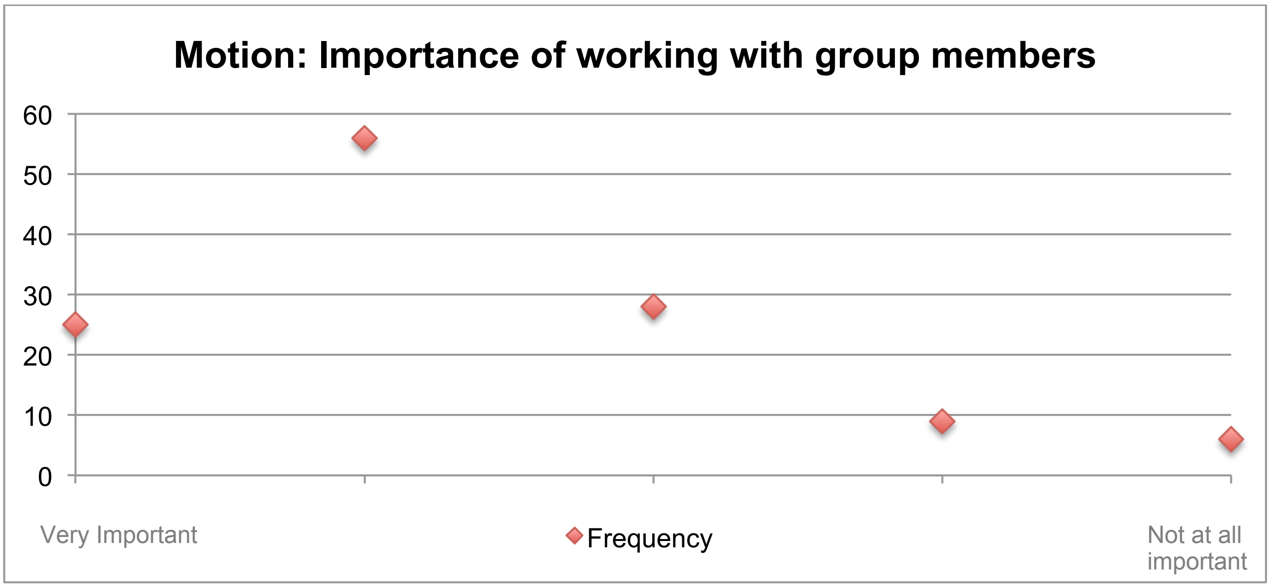
This survey is in 5 parts:

A. About You and Your Study
B. Your Preparation for the Engineering Foundation Classes
C. In Class and After
D. Your Experience of Learning Threshold Concepts and Understandings
E. Final Comments

This study has been approved by UWA Human Research and Ethics Committee, RA/4/1/5500.

Appendix 7 Questionnaire Part C Graphs





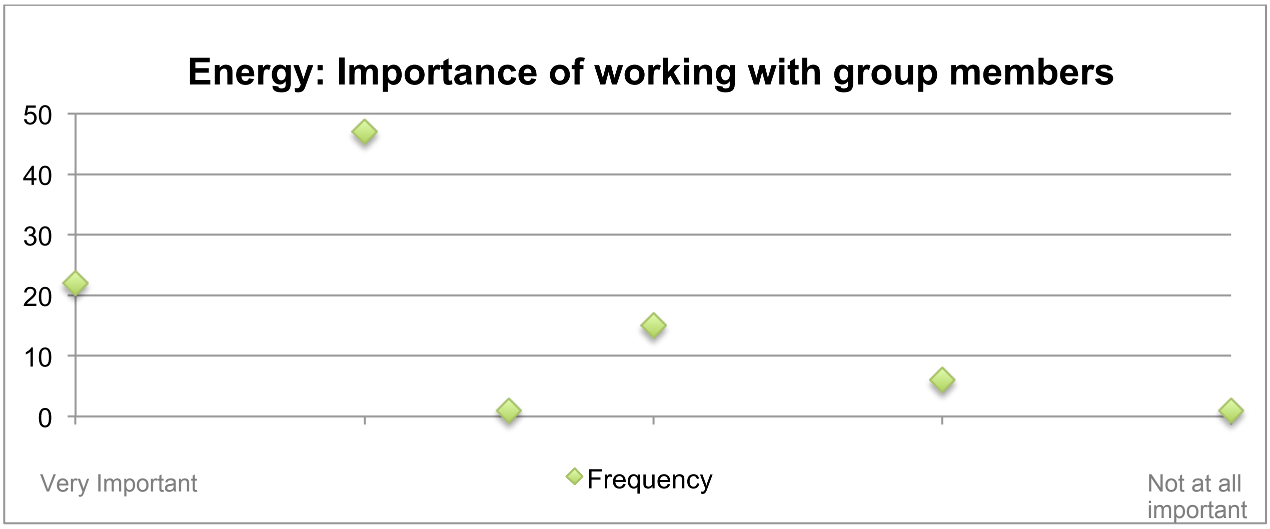
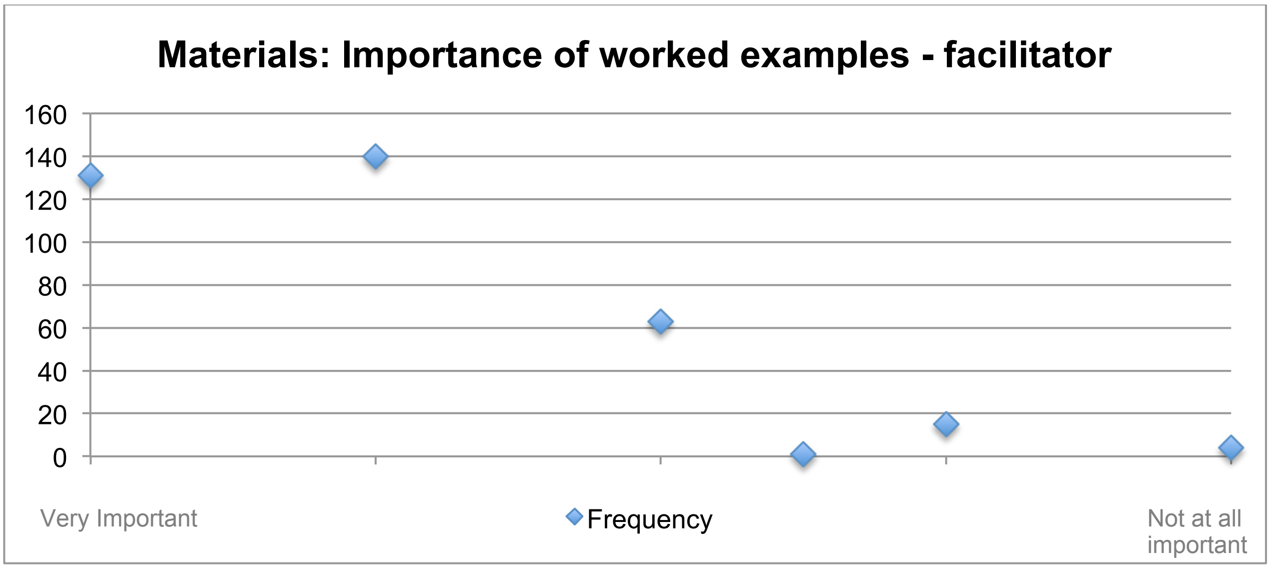
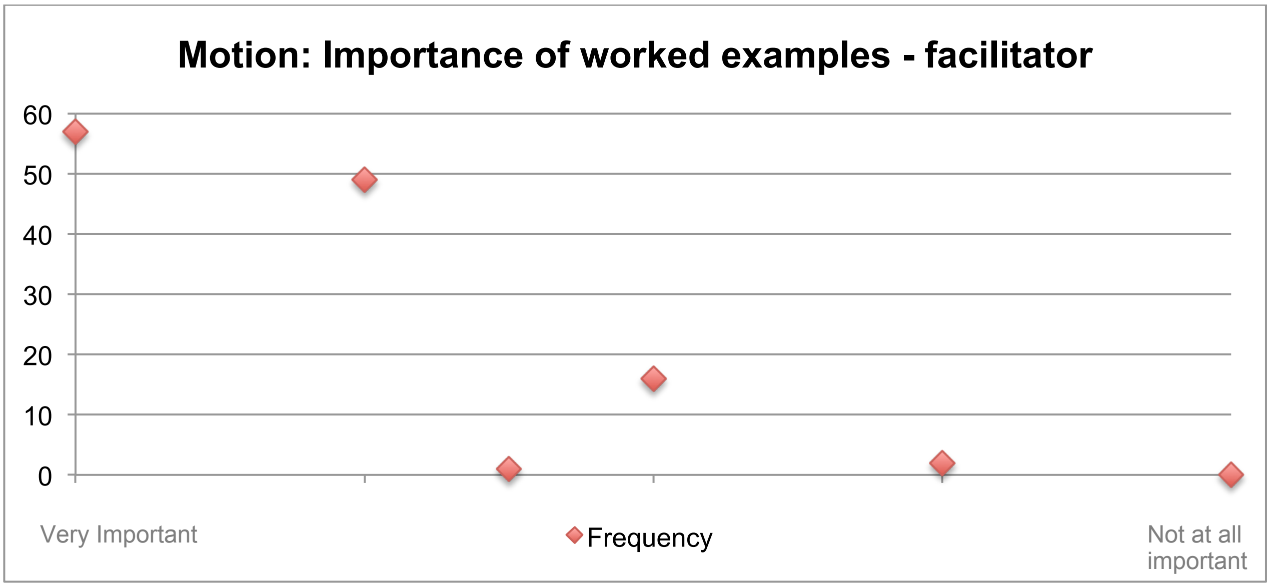


Figure 0.1 C1a. Importance of working with group members - all three units





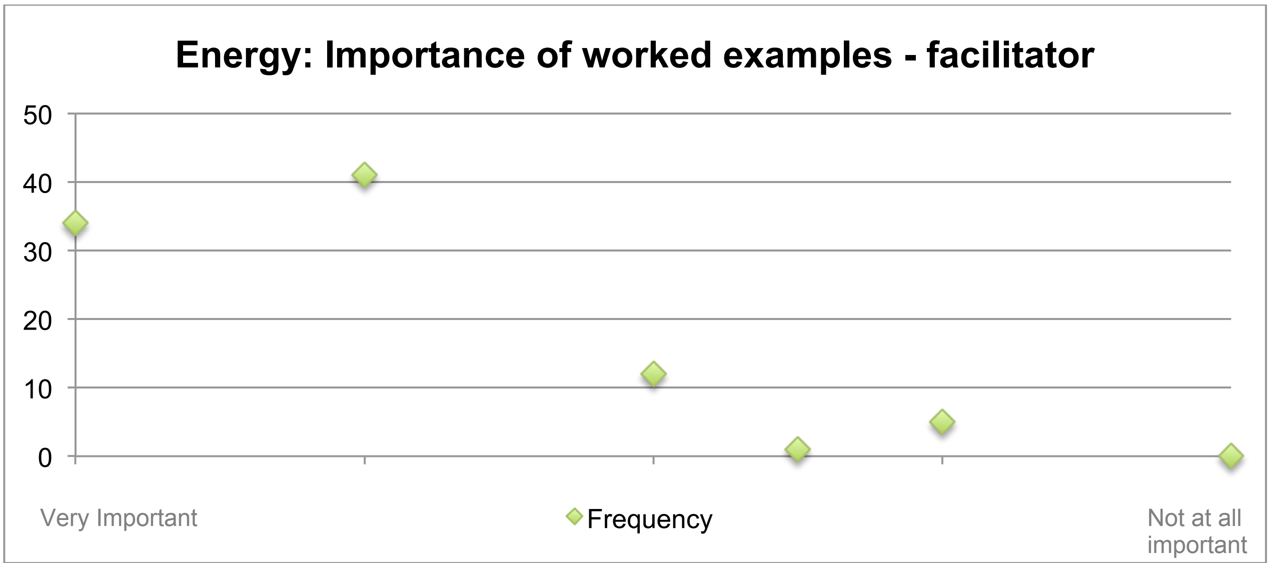
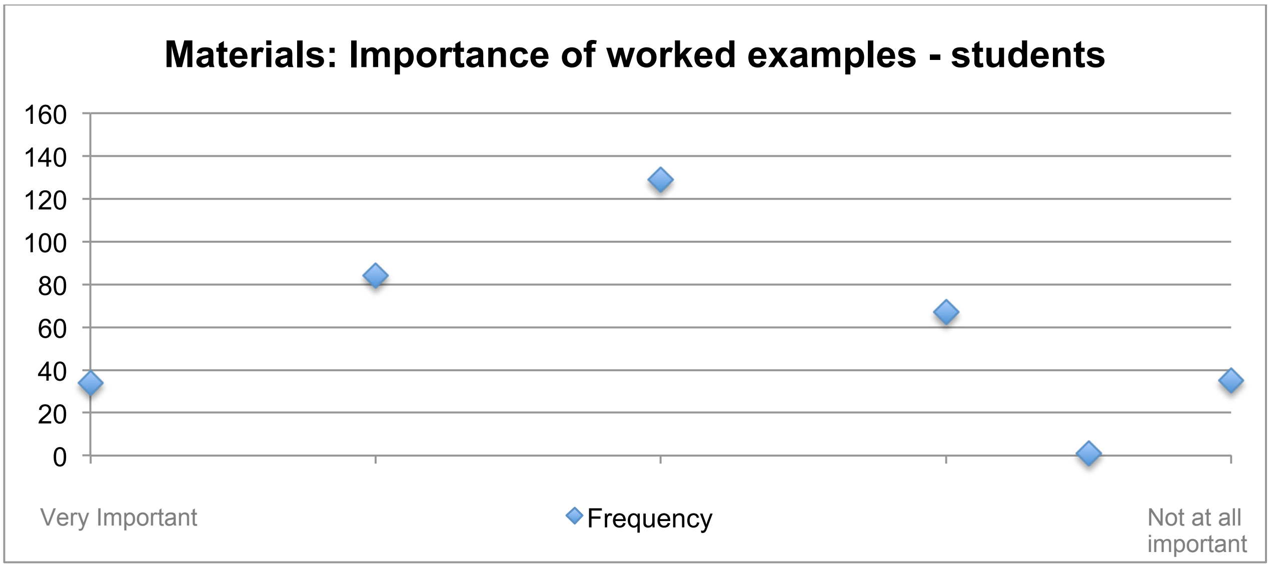
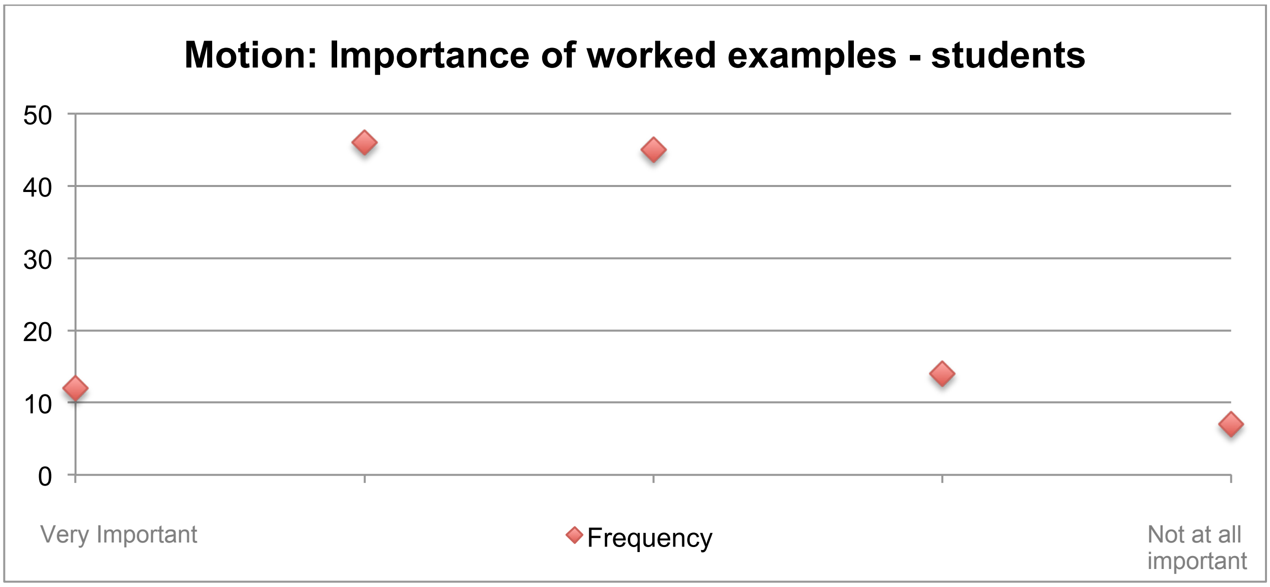


Figure 0.2 C1b. Importance of worked examples on the board by the facilitator – all three units





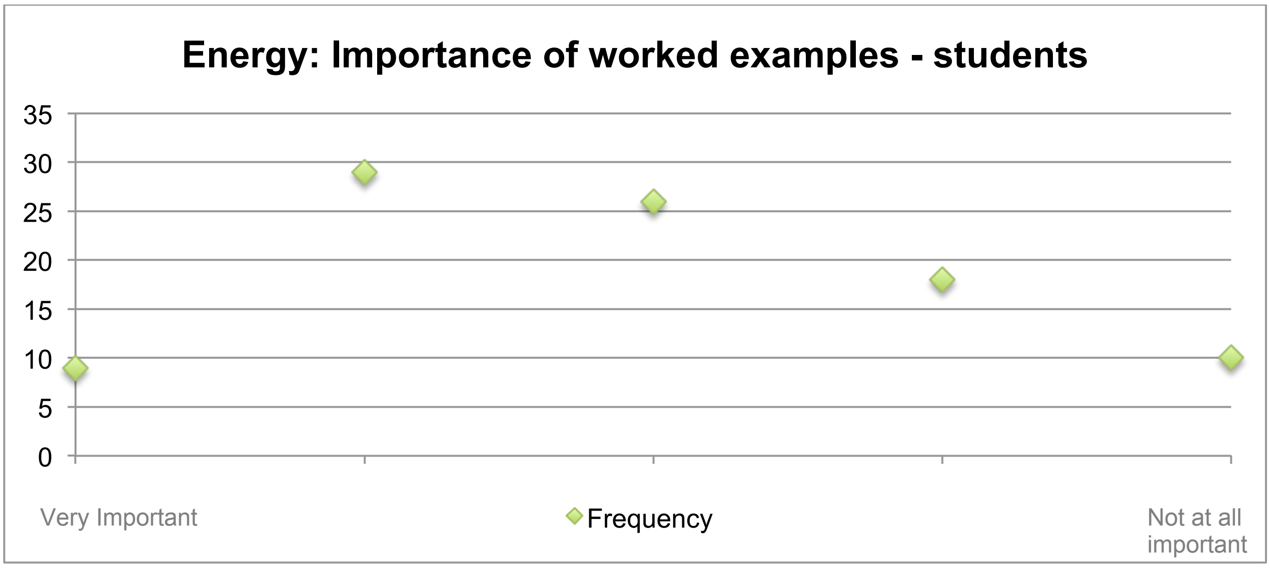
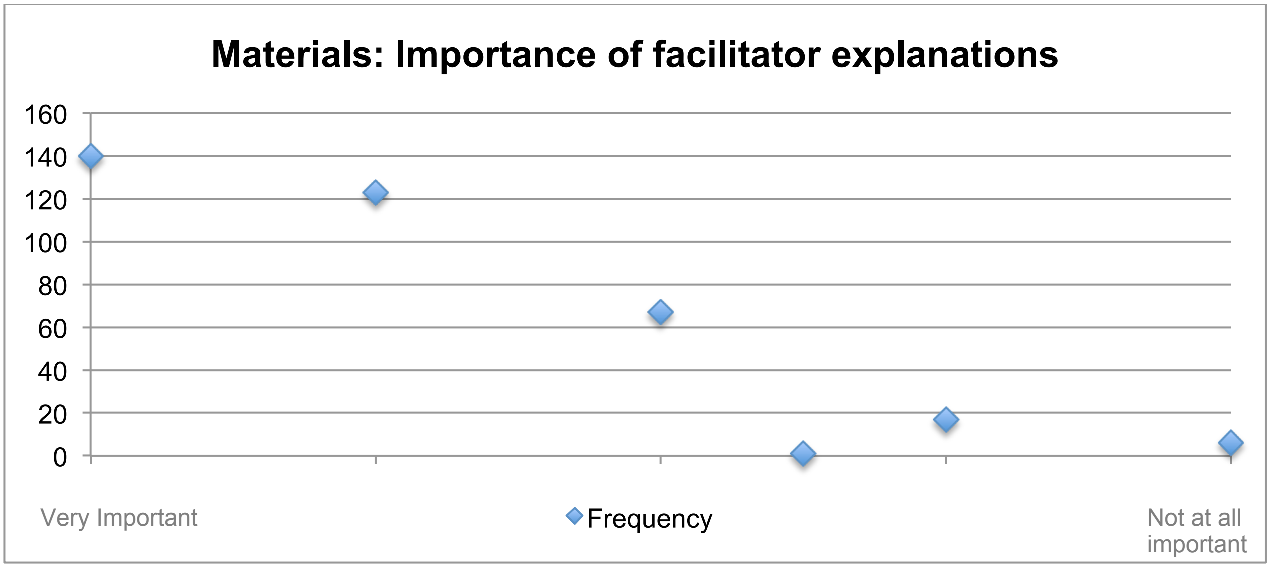
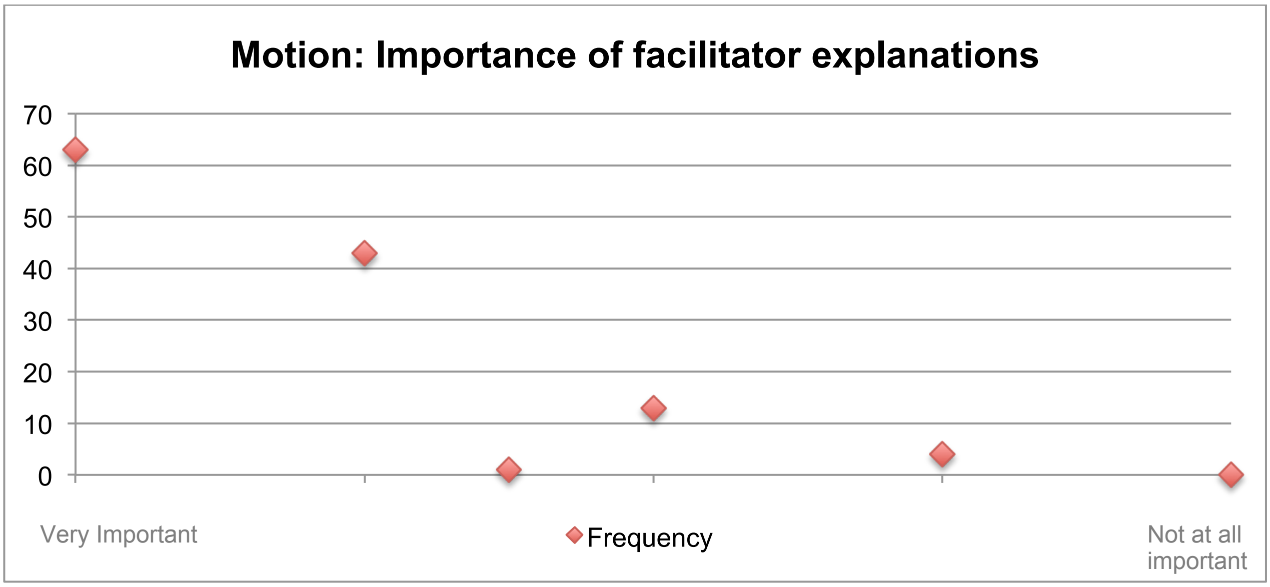


Figure 0.3 C1c. Importance of worked examples on the board by other students – all three units





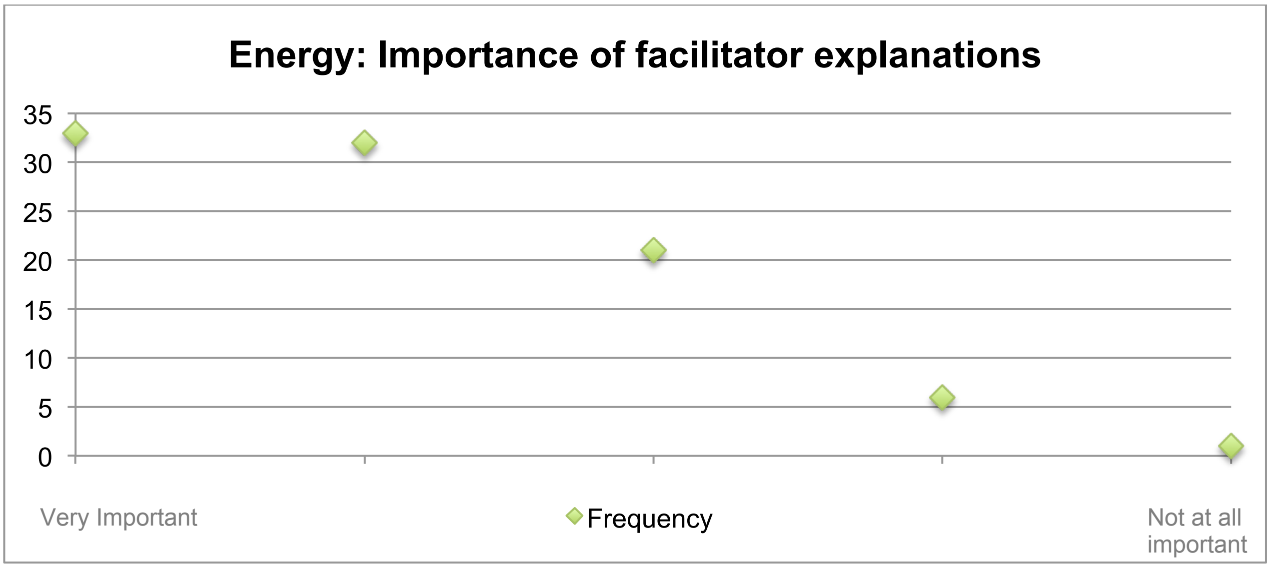
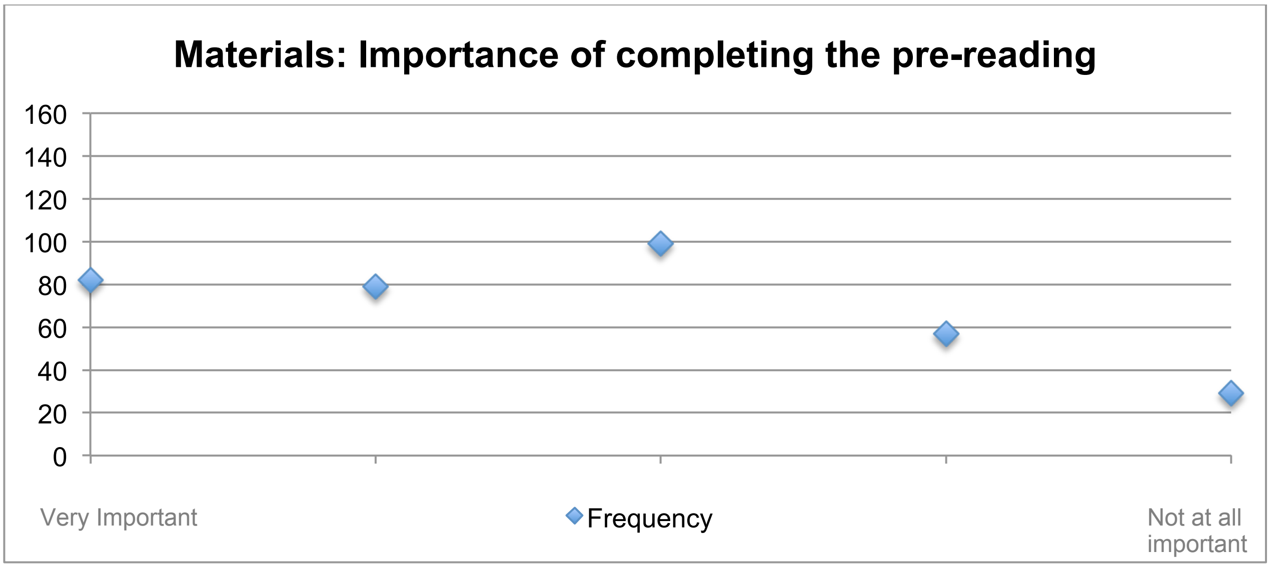
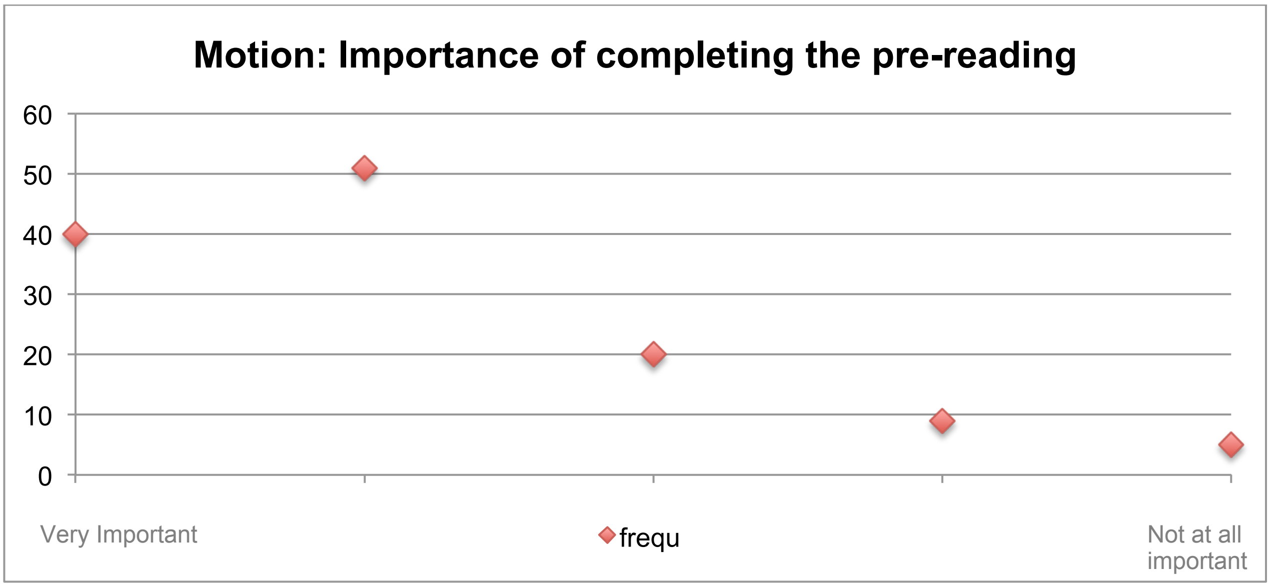


Figure 0.4 C1d. Importance of the explanations of the facilitator – all three units





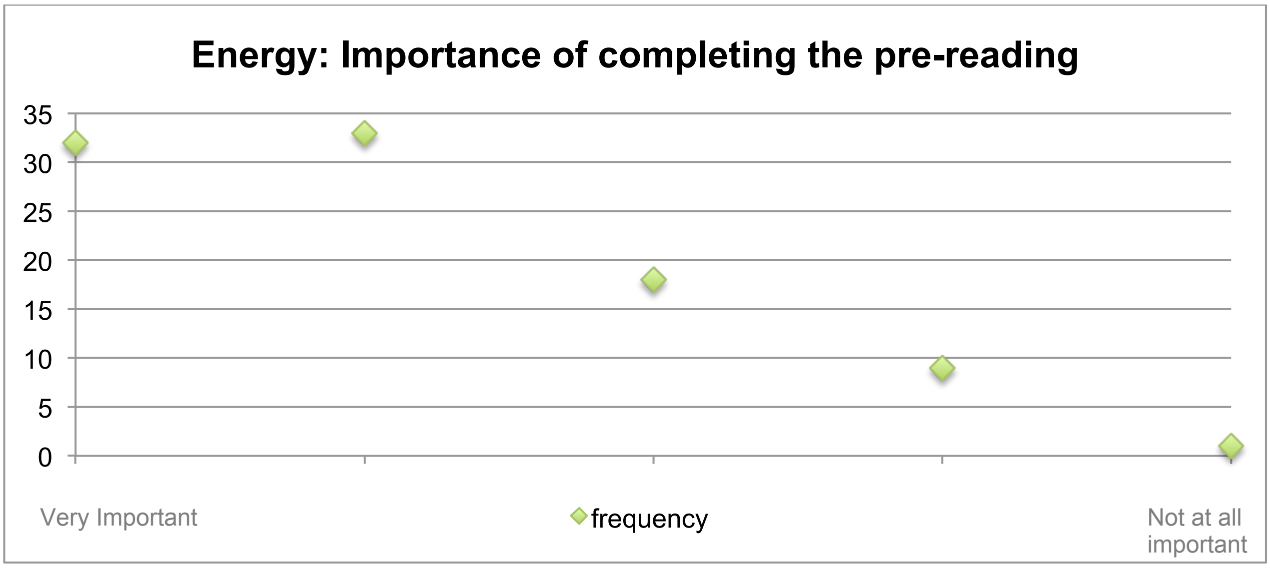
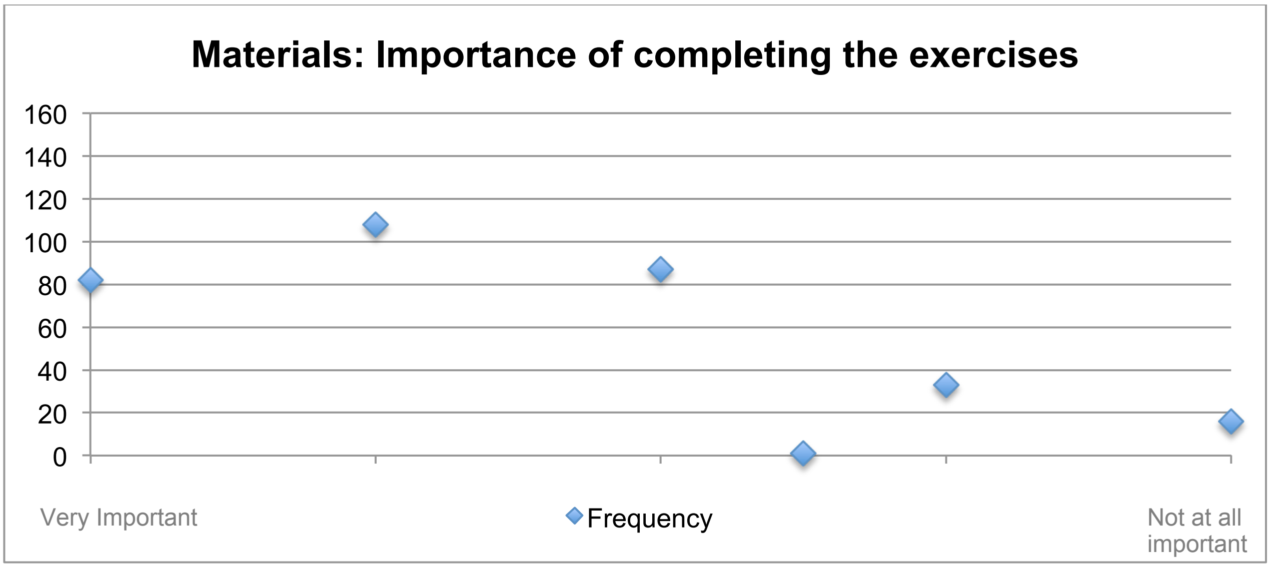
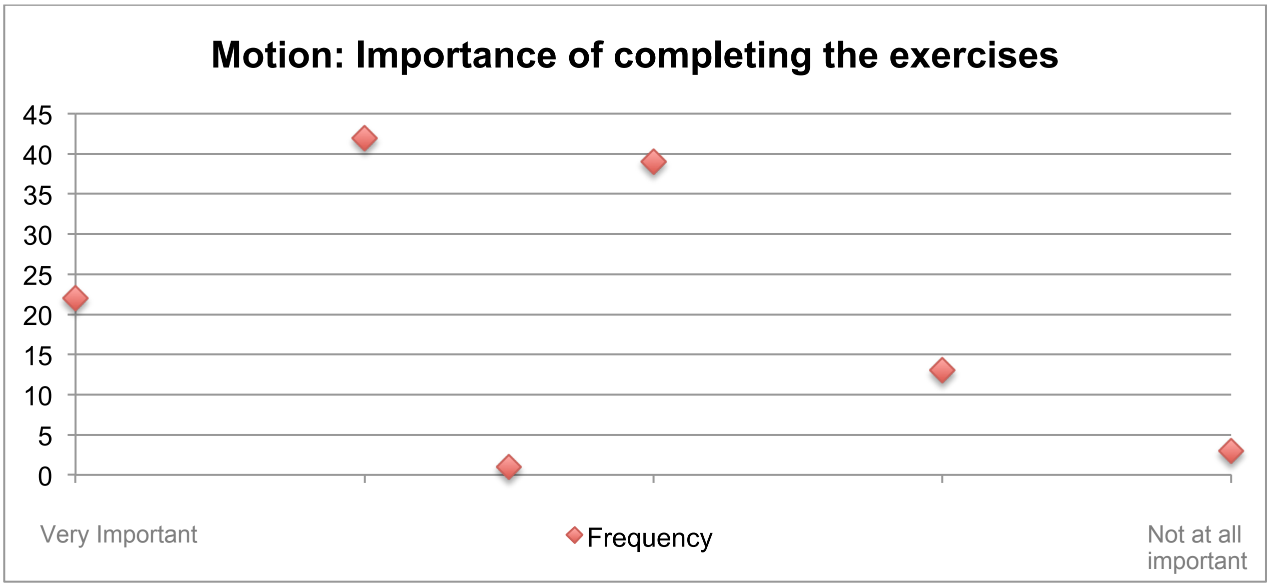


Figure 0.5 C1e. The importance of having completed the pre-reading - all three units





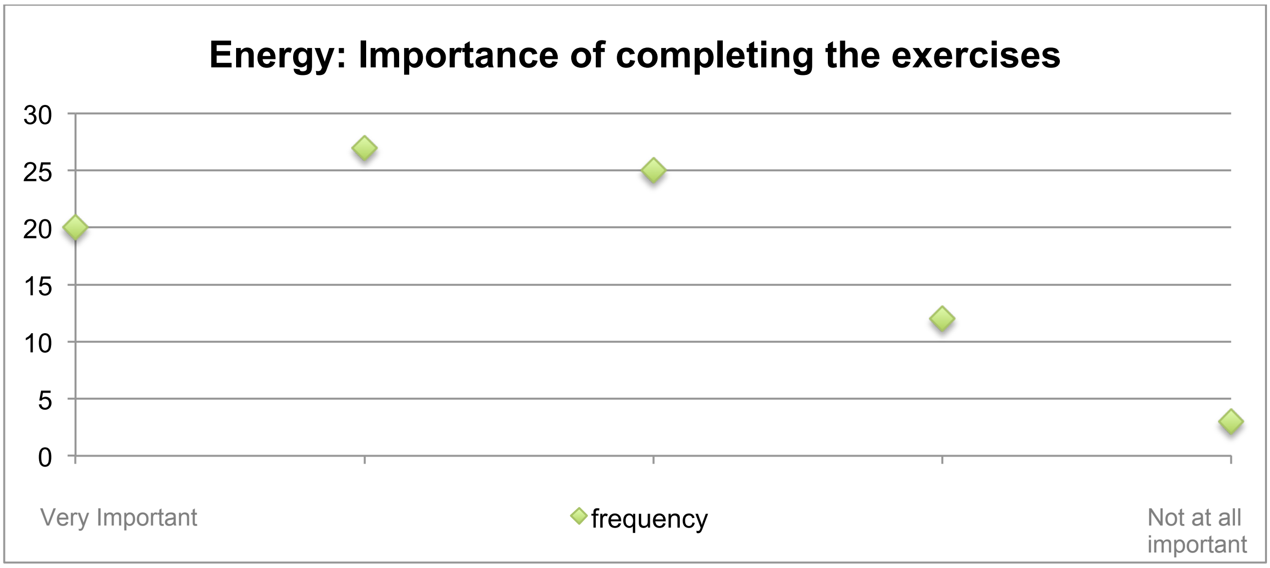


Figure 0.6 C1f. The importance of having completed the required exercises – all three units

8 Appendix 8 Questionnaire Part D Graphs

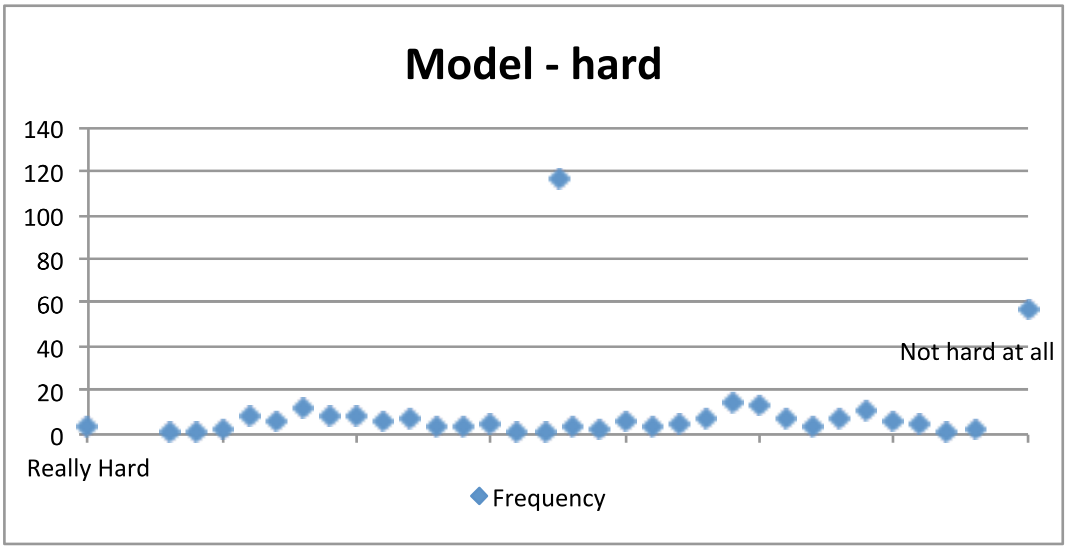
This appendix graphs the responses of students to questions about the threshold concepts encountered by Week 6 of three 13 week units, Materials, Motion and Energy.

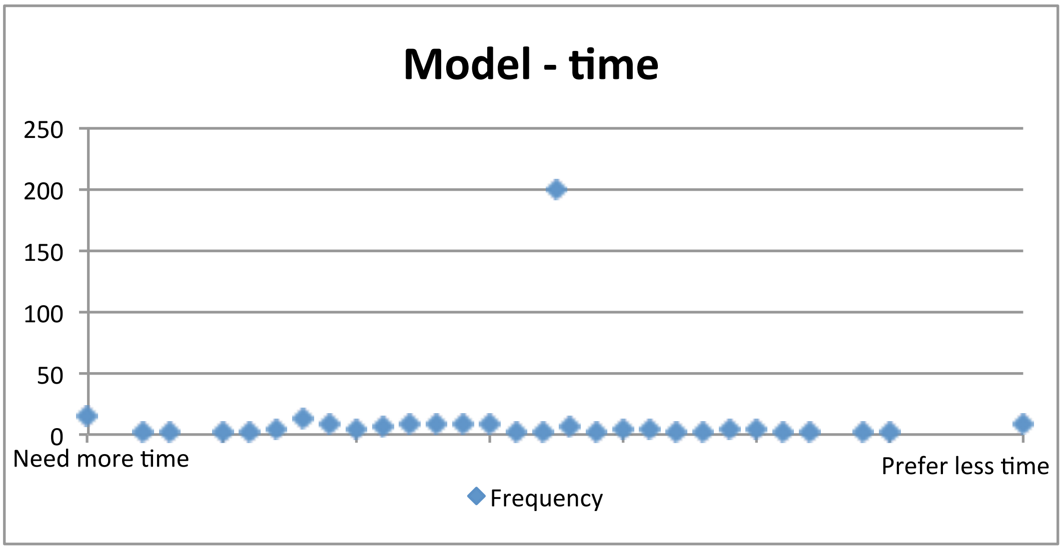
8.1 Materials

The questionnaire for materials questioned student experiences around seven threshold concepts. Three threshold concepts (*Modelling, Equilibrium, Stress / Strain*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in the following sections.

8.1.1 Modelling

Question D1 asked about the TC *Modelling*: Simplifying a physical system for analysis by choosing an appropriate *model* (e.g., a mathematical model) and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





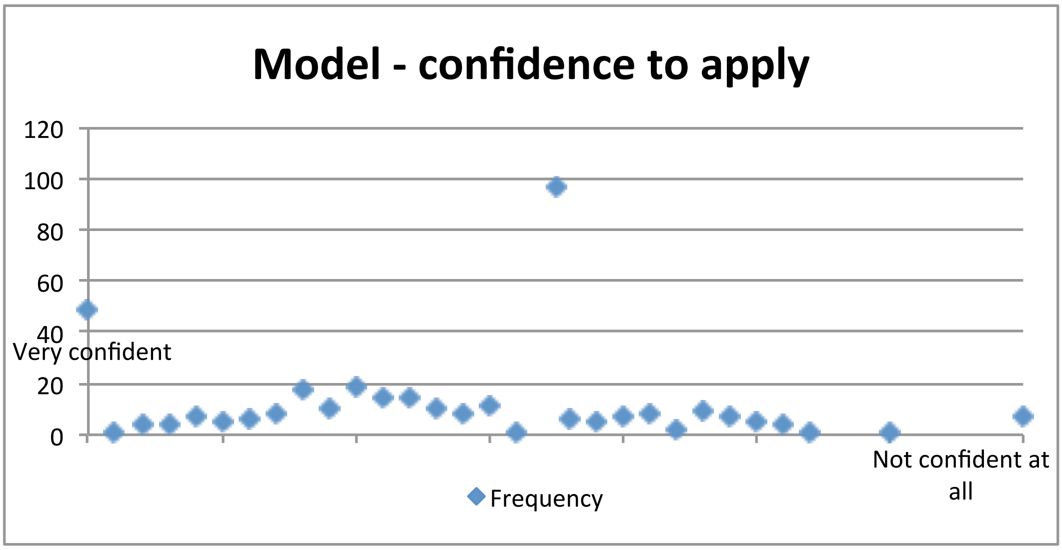
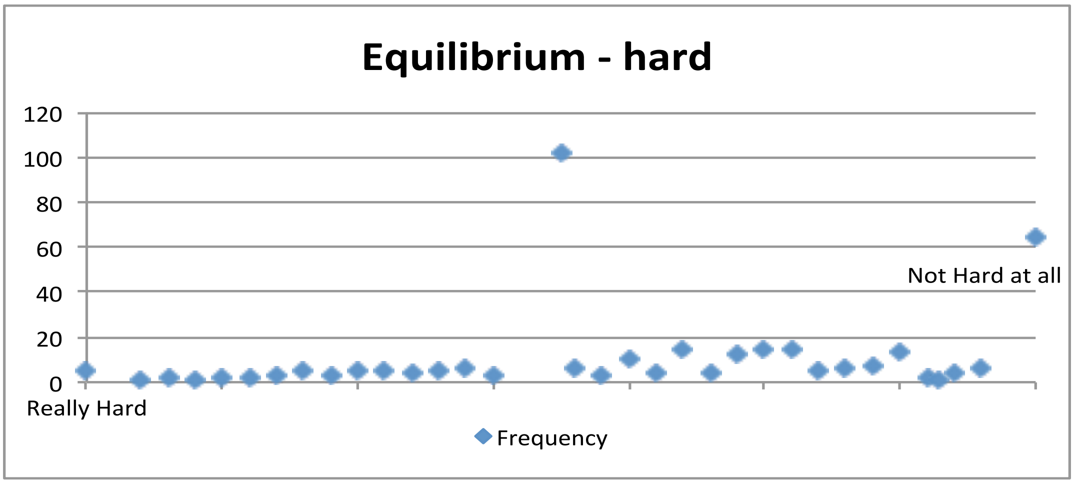


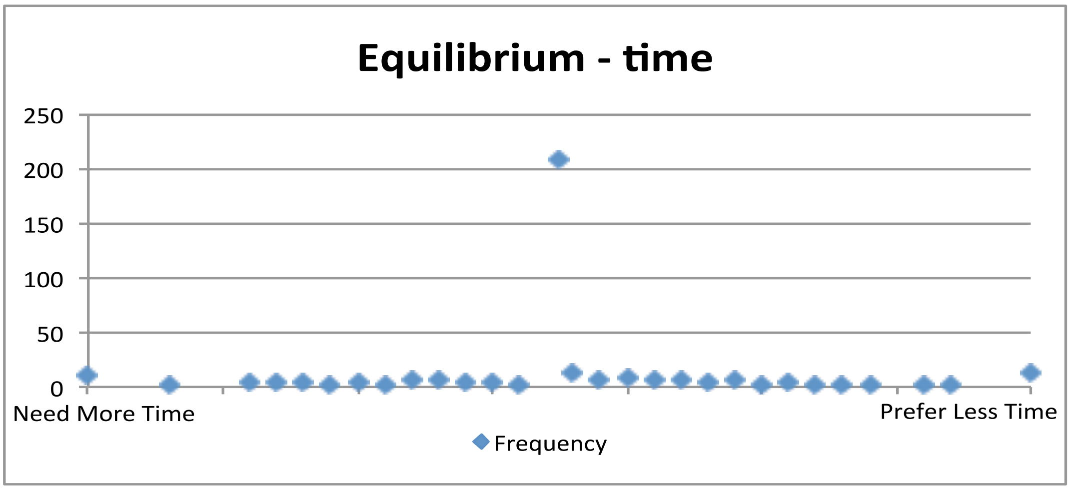
Figure 8.1 Materials: Responses around the TC Modelling

Students reported finding the TC *Modelling* neither hard nor easy, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

8.1.2 Equilibrium

Question D2 asked about the TC *Equilibrium*: All systems and their parts tend to equilibrium, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





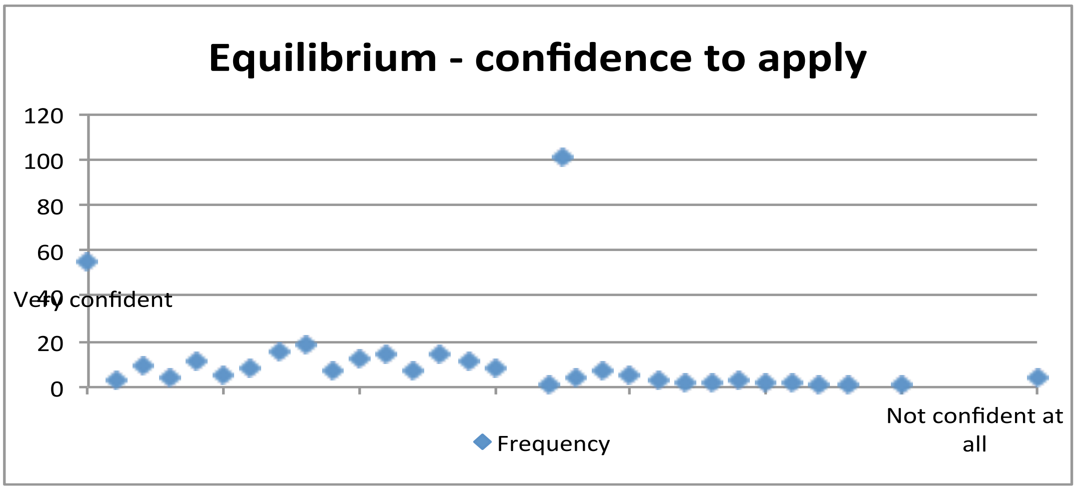


Figure 8.2 Materials: Responses around the TC Equilibrium

Students reported finding the TC *Equilibrium* more easier than hard, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

8.1.3 Stress / Strain

Question D3 asked about the TC *Stress / Strain*: The relationship between stress and strain, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.

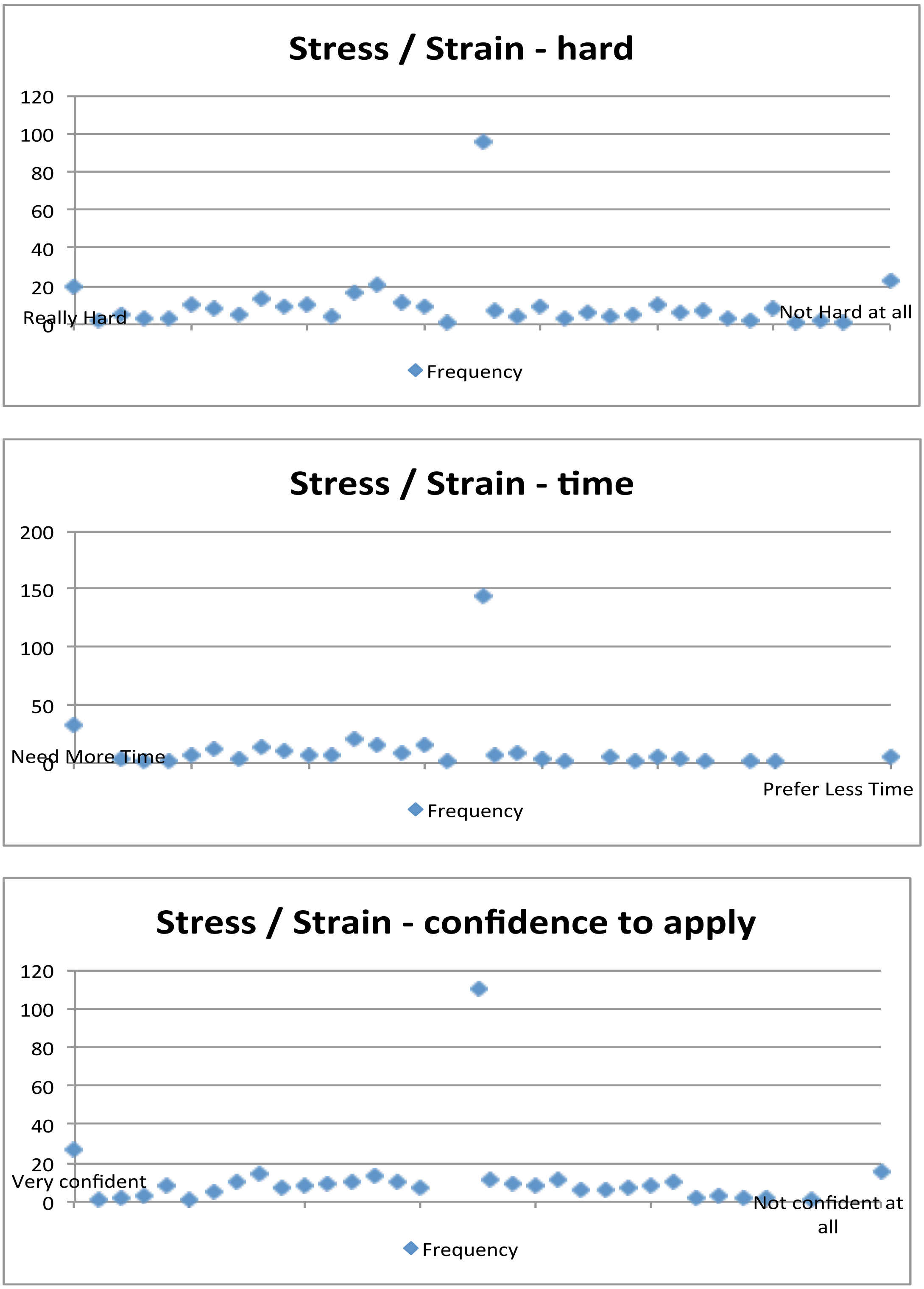
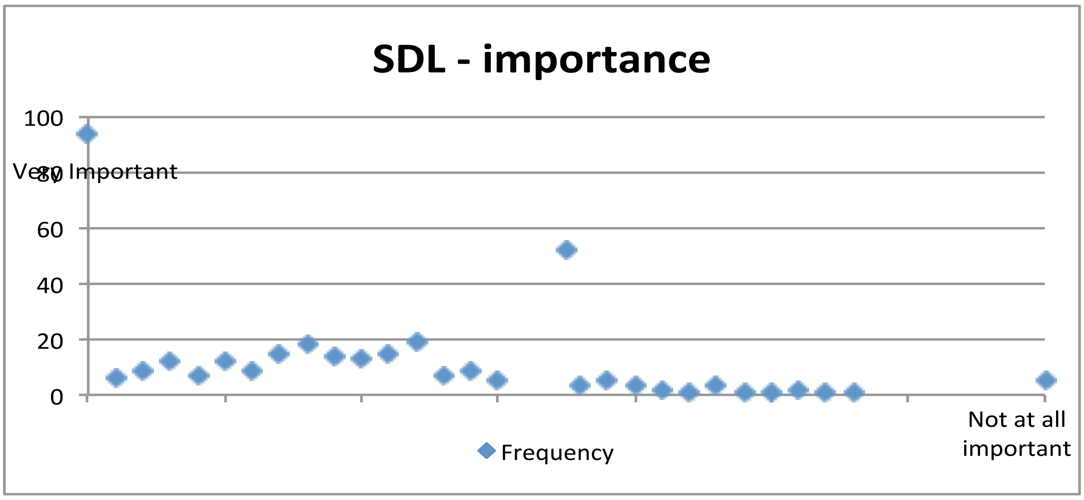


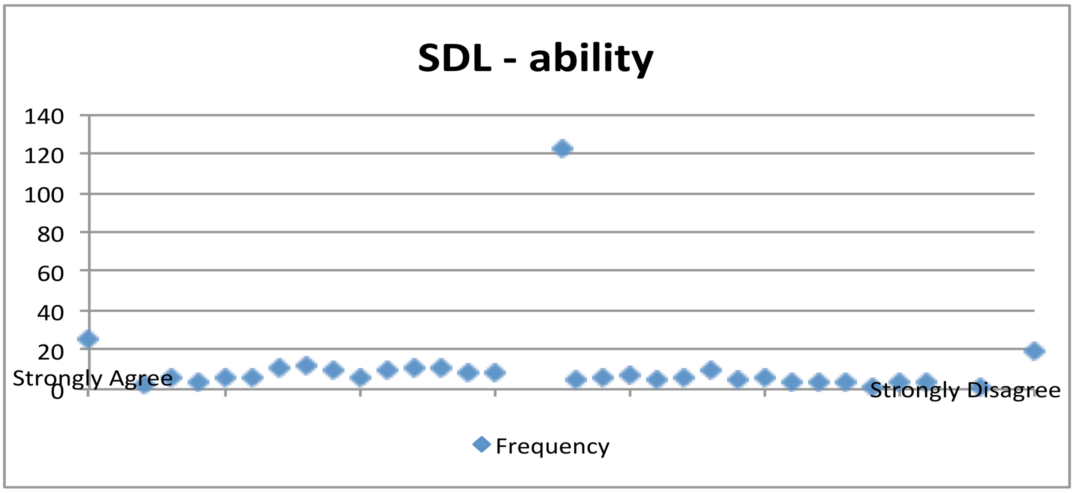
Figure 8.3 Materials: Responses around the TC Stress / Strain

Students reported finding the TC *Stress / Strain* more harder than easier, preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

8.1.4 Self Driven Learning

Question D4 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources*", three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*? The responses to the three questions are graphed below.





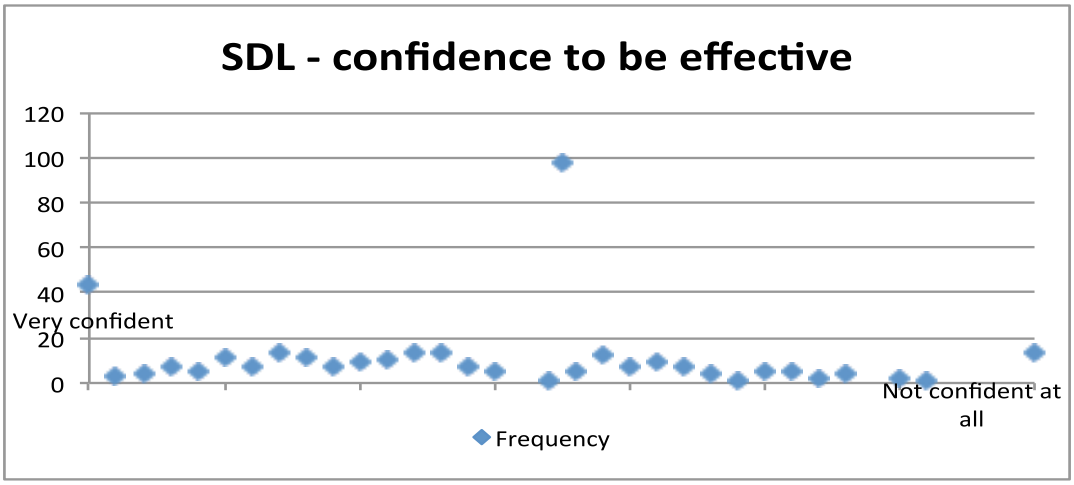
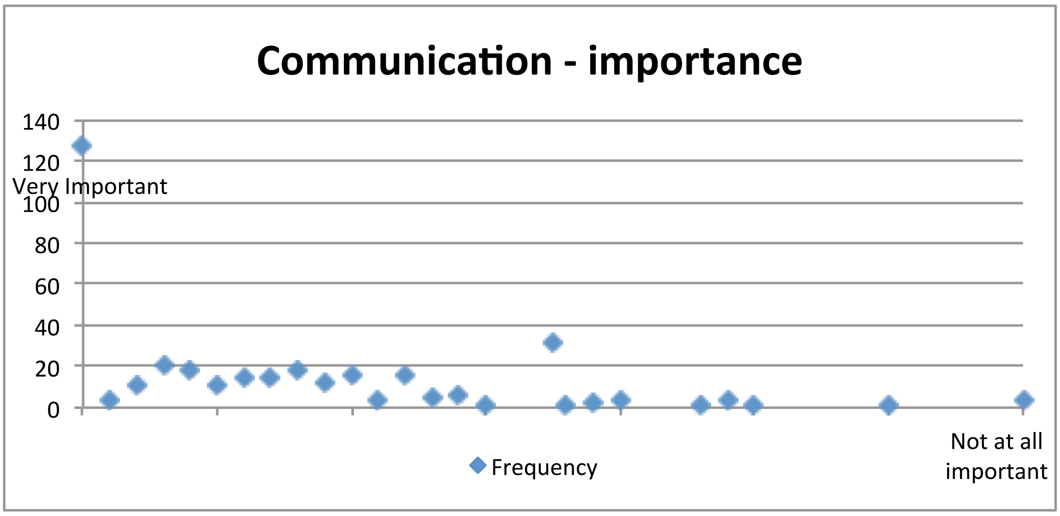


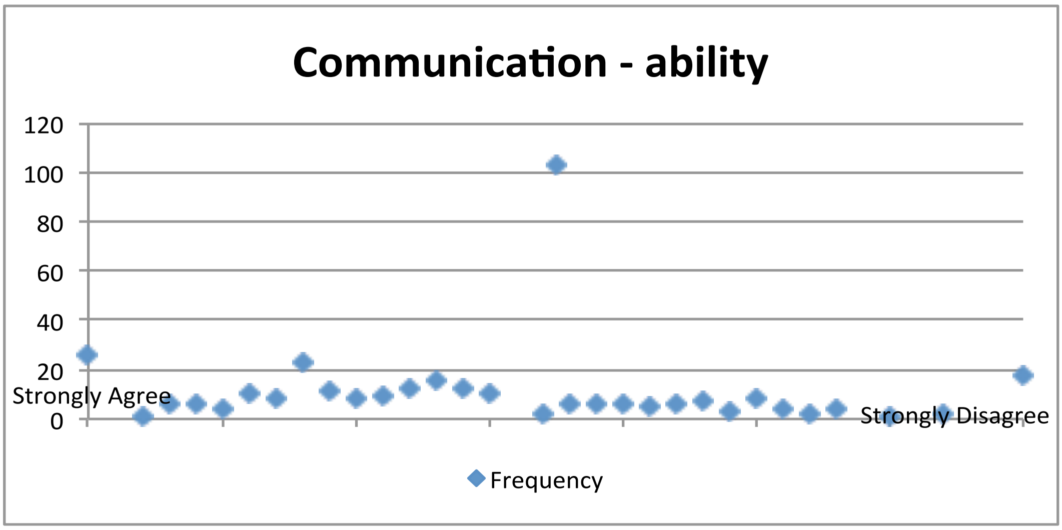
Figure 8.4 Materials: Responses around the TC Self-Driven Learning

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, neither agreed nor disagreed that their ability to self-drive their learning had increased since the start of this unit, and felt confident in their abilities to be an effective self-driven learner.

8.1.5 Communication

Question D5 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice"*, three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*? The responses to the three questions are graphed below.





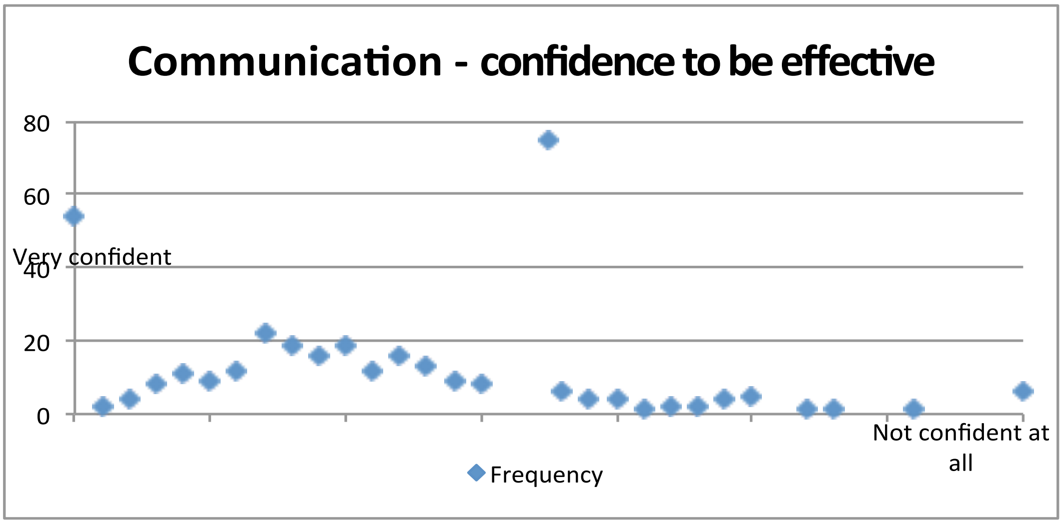
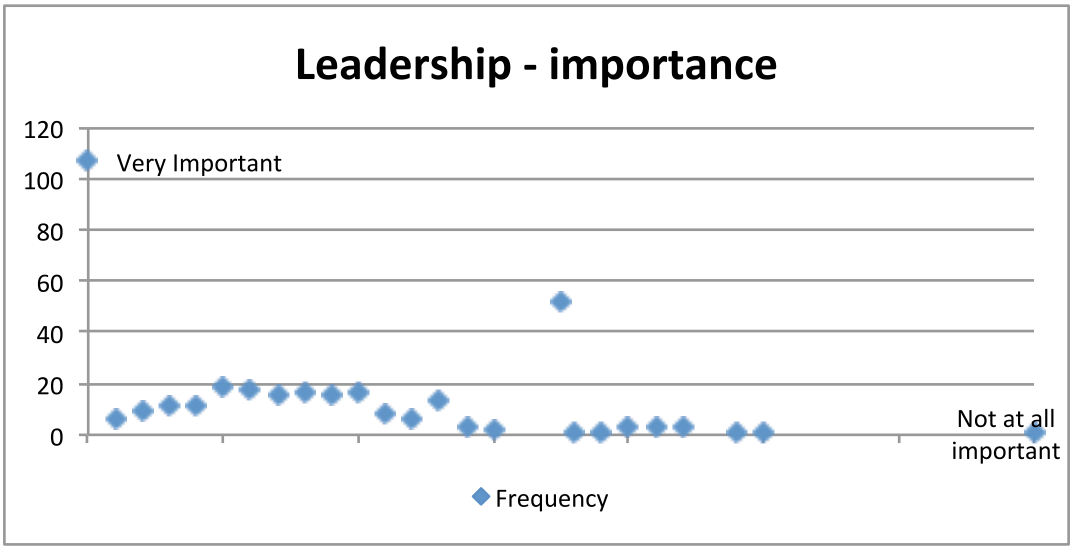


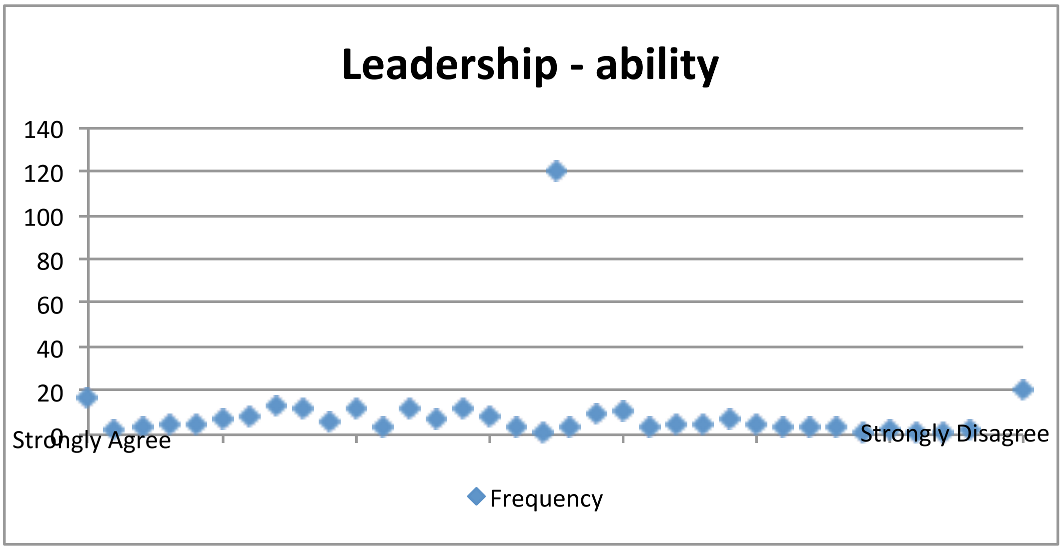
Figure 8.5 Materials: Responses around the TC Communication

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective communicator.

8.1.6 Leadership

Question D6 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority"*, three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*? The responses to the three questions are graphed below.





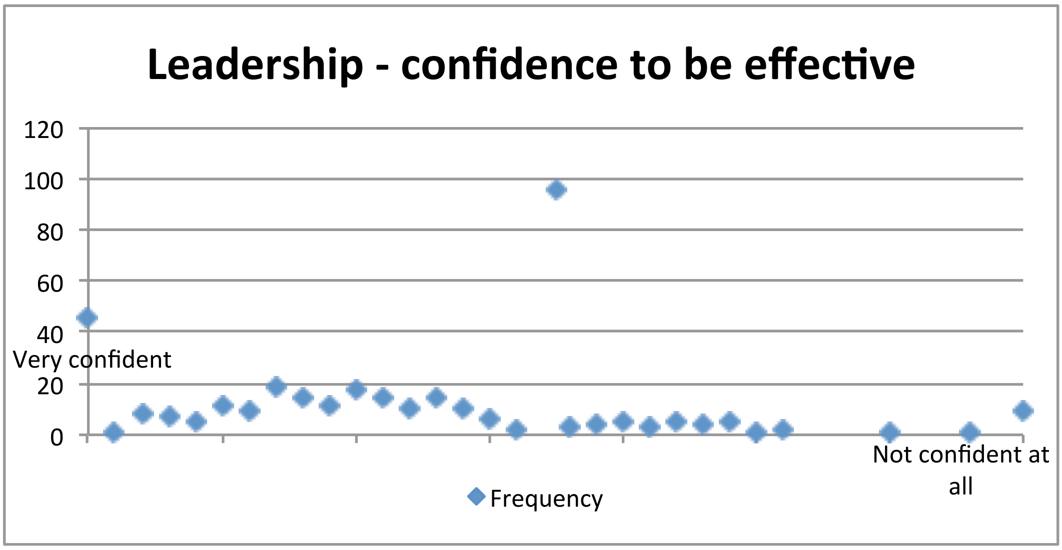
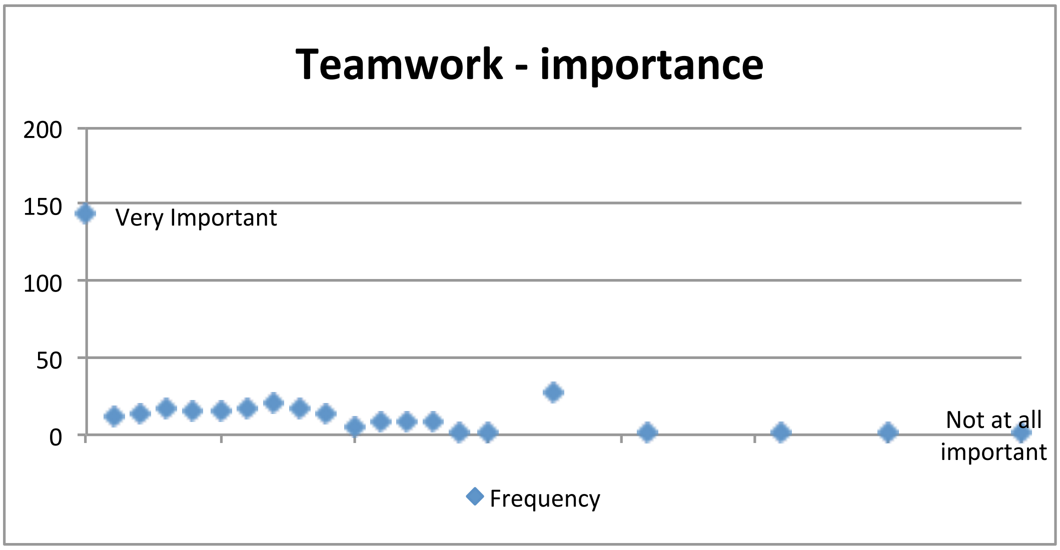


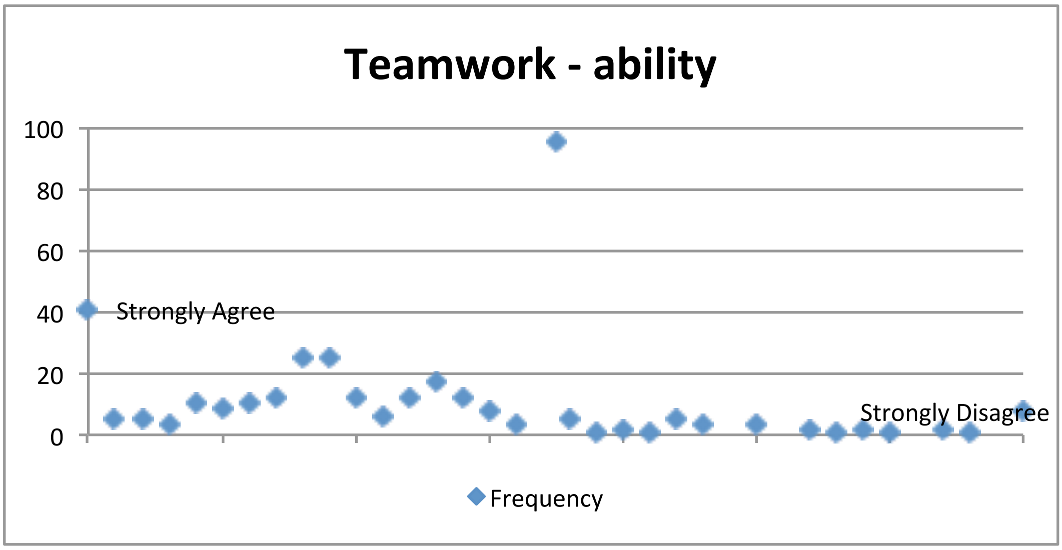
Figure 8.6 Materials: Responses around the TC Leadership

Students acknowledged the importance of the TC *Leadership* to successful engineering practice, agreed more than disagreed that their ability to lead had increased since the start of this unit, and felt strongly confident in their abilities to be an effective leader.

8.1.7 Teamwork

Question D7 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone*", three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*? The responses to the three questions are graphed below.





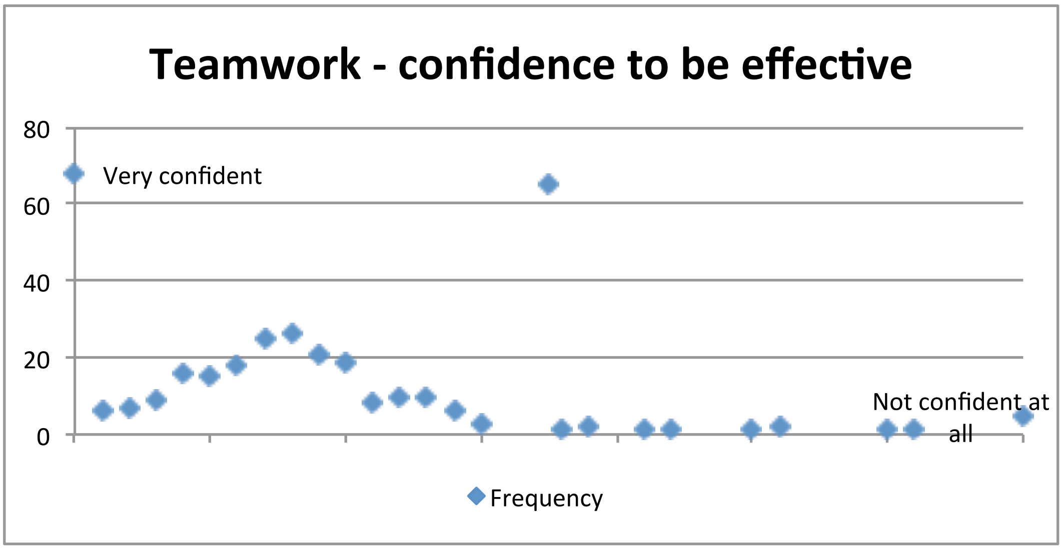


Figure 8.7 Materials: Responses around the TC Teamwork

Students acknowledged the importance of the TC *Teamwork* to successful engineering practice, agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and felt strongly confident in their abilities to be an effective team player.

8.1.8 Summary – Materials TC

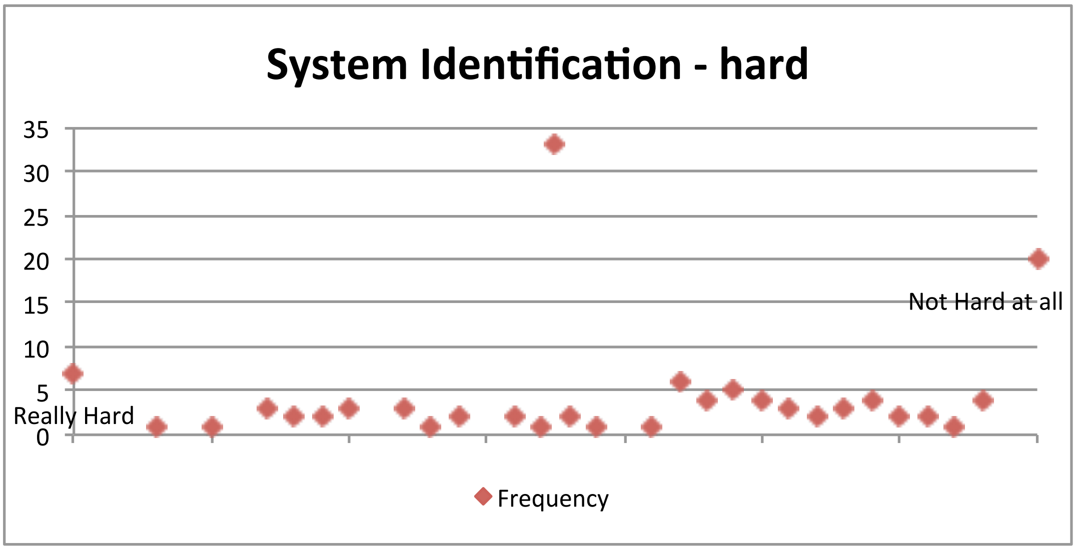
At this stage of the Semester, students reported finding the unit specific threshold concepts as being neither hard nor easy, had no preference around allocating more or less time to the TCs in the units, and felt confident in their abilities to apply the TC to the material covered so far in the unit. Students acknowledged the importance of the four common engineering TCs, *Self-Driven Learning, Communication, Leadership* and *Teamwork*, and felt confident in their abilities in those four areas. They acknowledged a slight growth in abilities in the four common engineering TCs since the start of the unit.

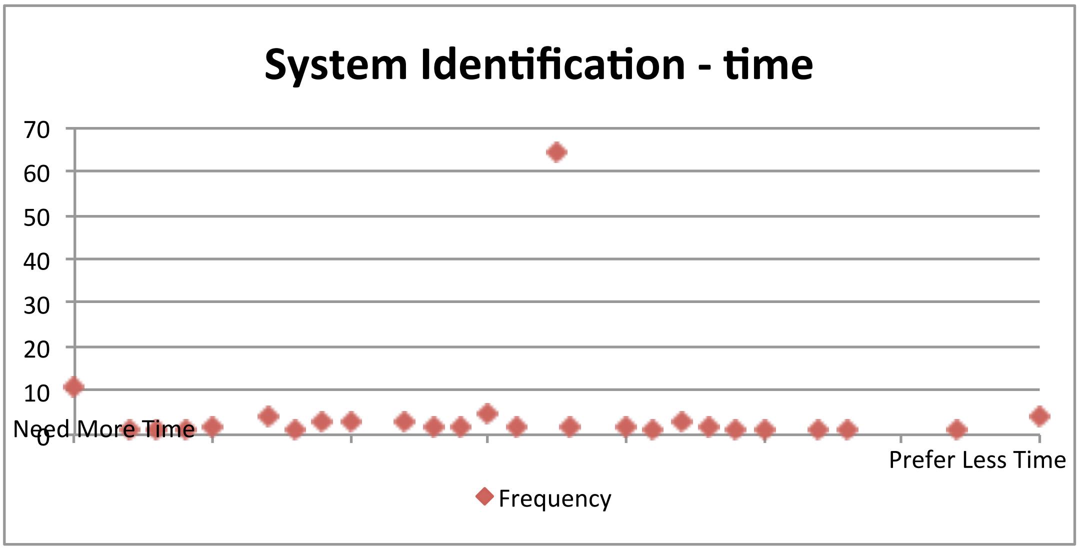
8.2 Motion

The questionnaire for Motion also questioned student experiences around seven threshold concepts. Three threshold concepts (*Modelling, System Identification* and *Conservation Laws*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in the following sections.

8.2.1 System Identification

Question D1 asked about the TC *System Identification*: Identifying and defining the *system* (noting system boundaries) is a useful starting point in analysing and simplifying a system and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? This TC was also part of the Energy unit. The responses to the three questions are graphed below.





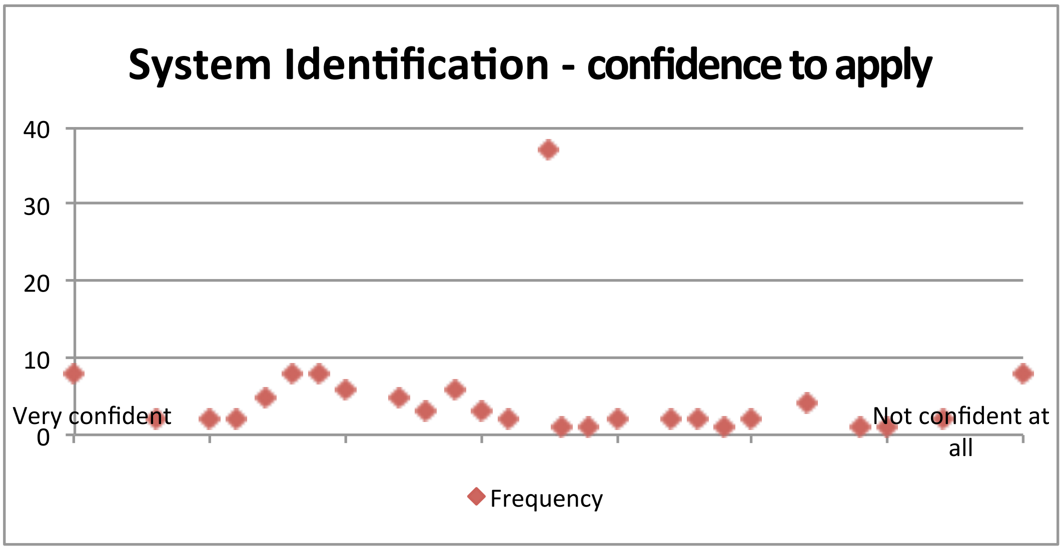
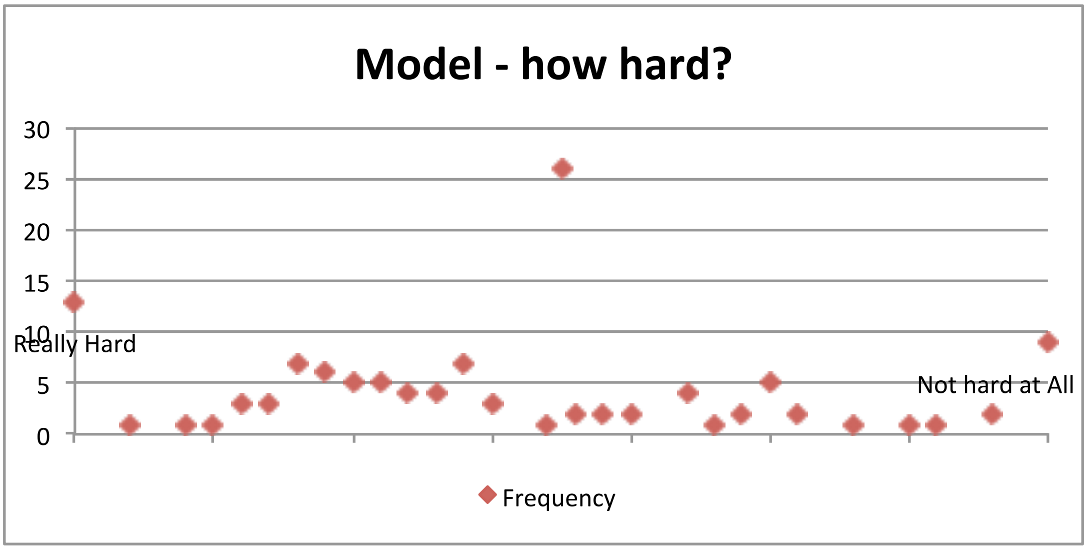


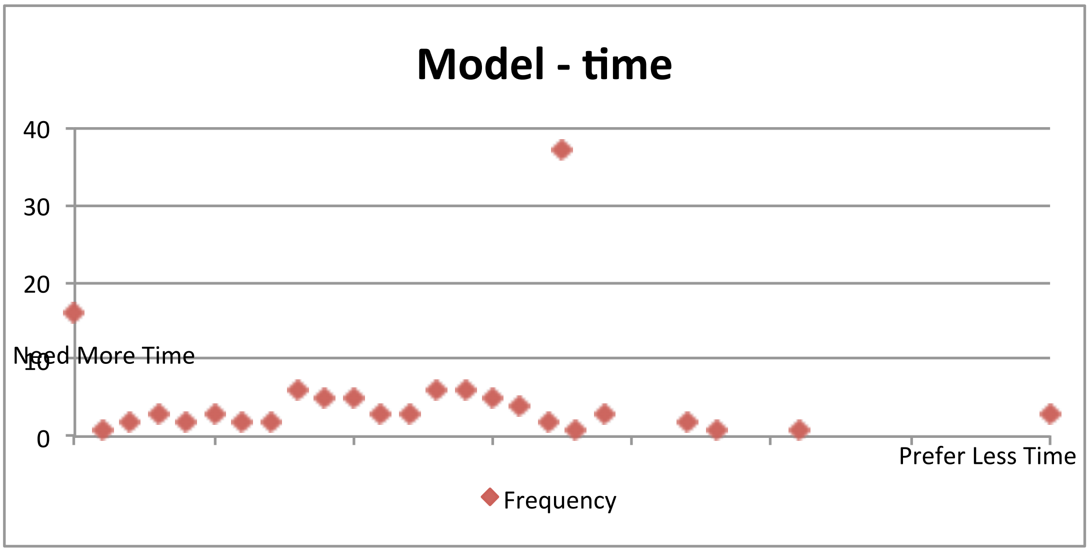
Figure 8.8 Motion: Responses around the TC System Identification

Students reported finding the TC *System Identification* neither hard nor easy, had no preference for more or less time, and felt confident in applying this TC to the material covered so far in this unit.

8.2.2 Modelling

Question D2 asked about the TC *Modelling*: In solving a circuit problem (identifying the voltages, currents, etc), the circuit can be simplified for analysis by choosing an appropriate circuit *model,* asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





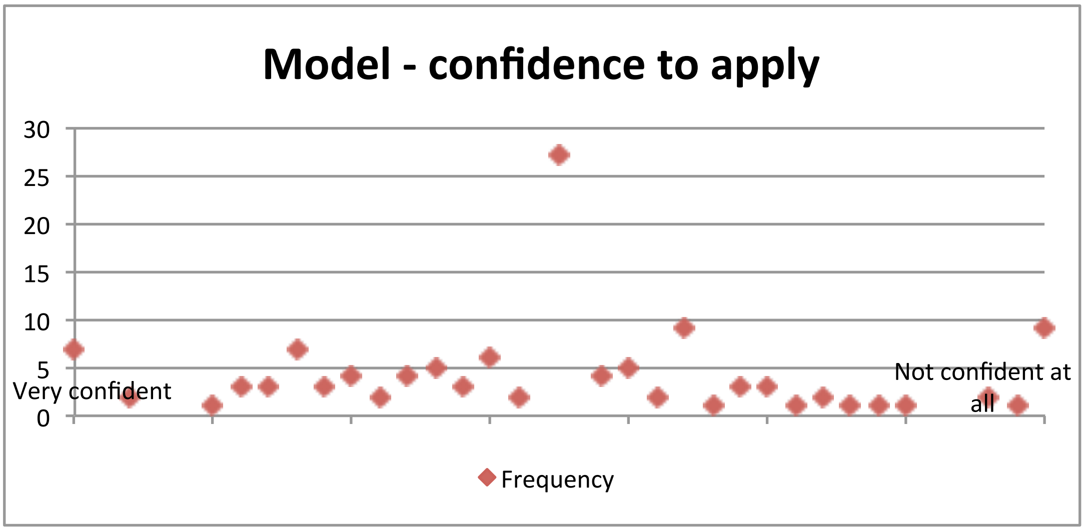
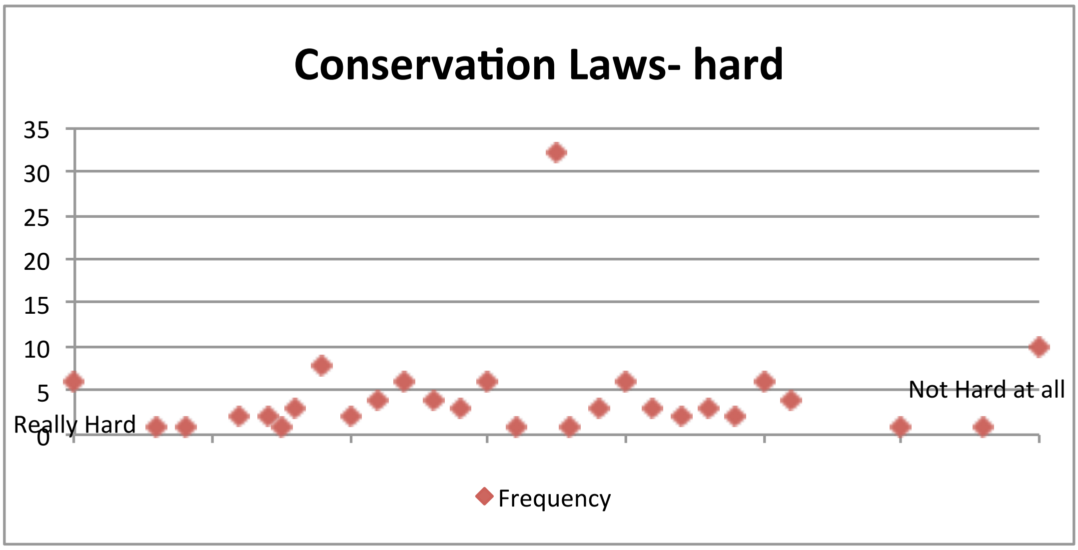


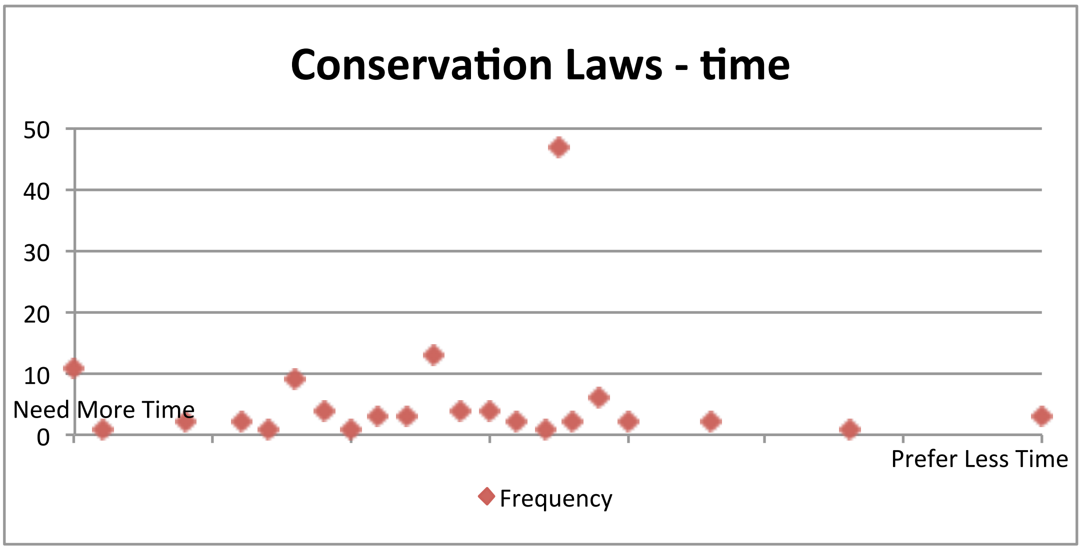
Figure 8.9 Motion: Responses around the TC Modellling

Students reported finding the TC System *Modelling* slightly harder than easier, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

8.2.3 Conservation Laws

Question D3 asked about the TC *Conservation Laws*: Conservations laws can be used to analyse a system - for example, conservation laws for charge and energy can be used to analyse electrical circuits and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





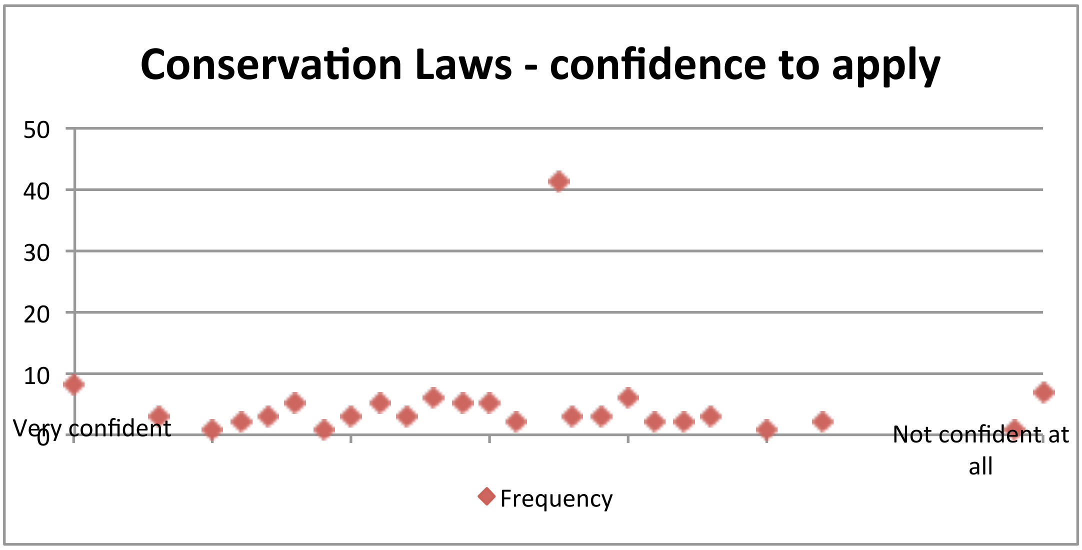
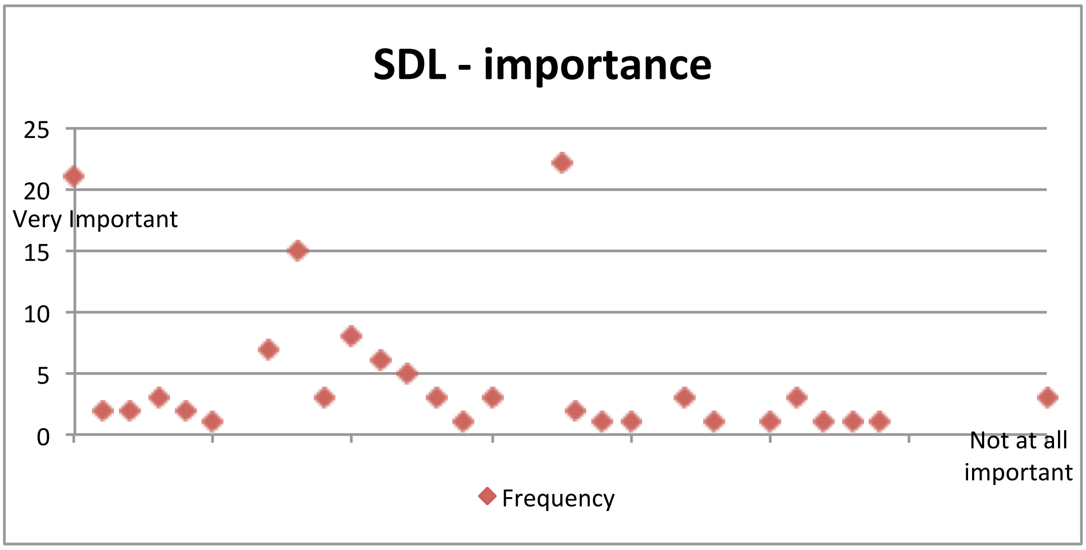


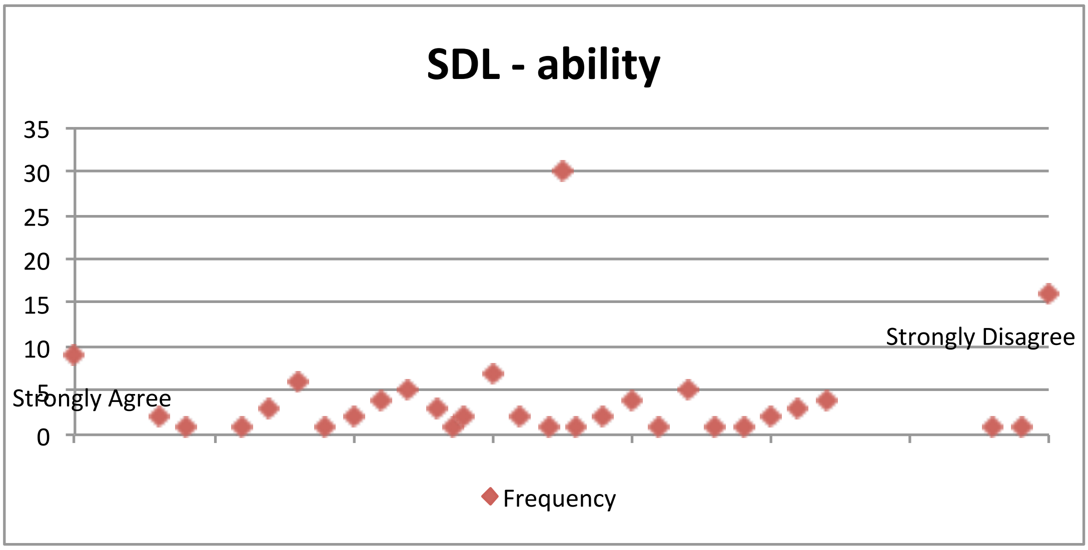
Figure 8.10 Motion: Responses around the TC Motion Laws

Students reported finding the TC *Conservation Laws* neither hard nor easy, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

8.2.4 Self Driven Learning

Question D4 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources*", three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*? The responses to the three questions are graphed below.





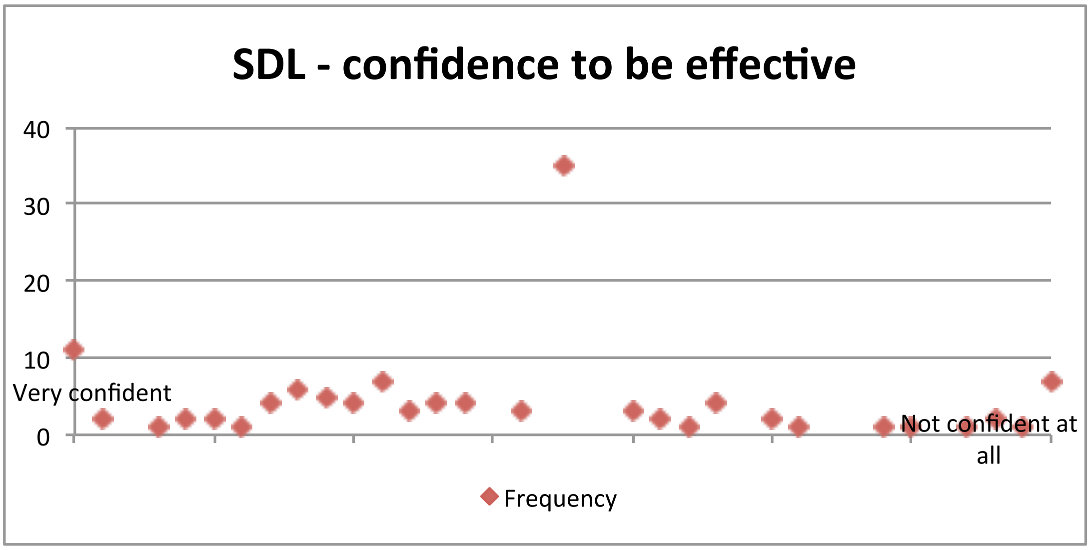
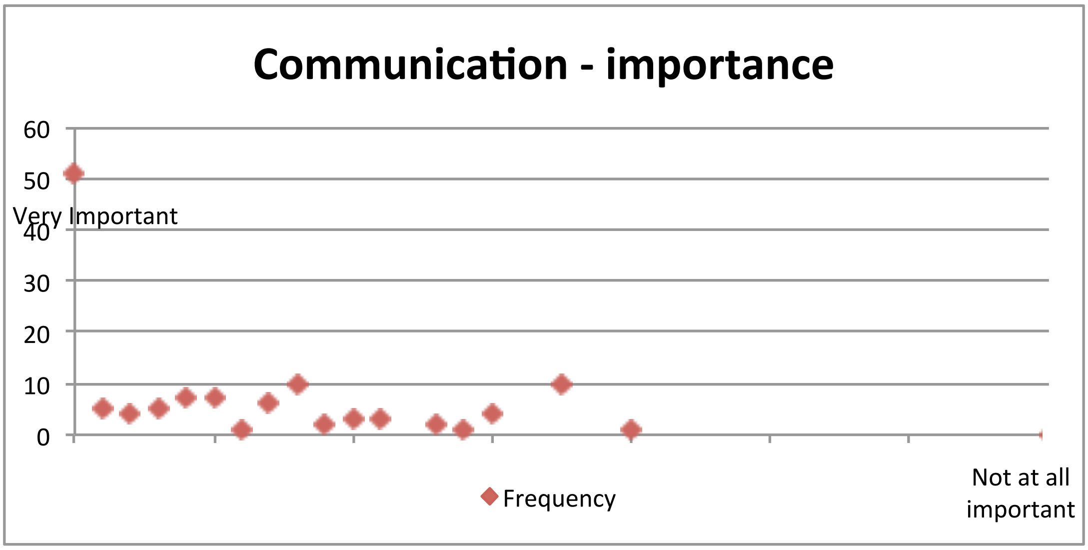


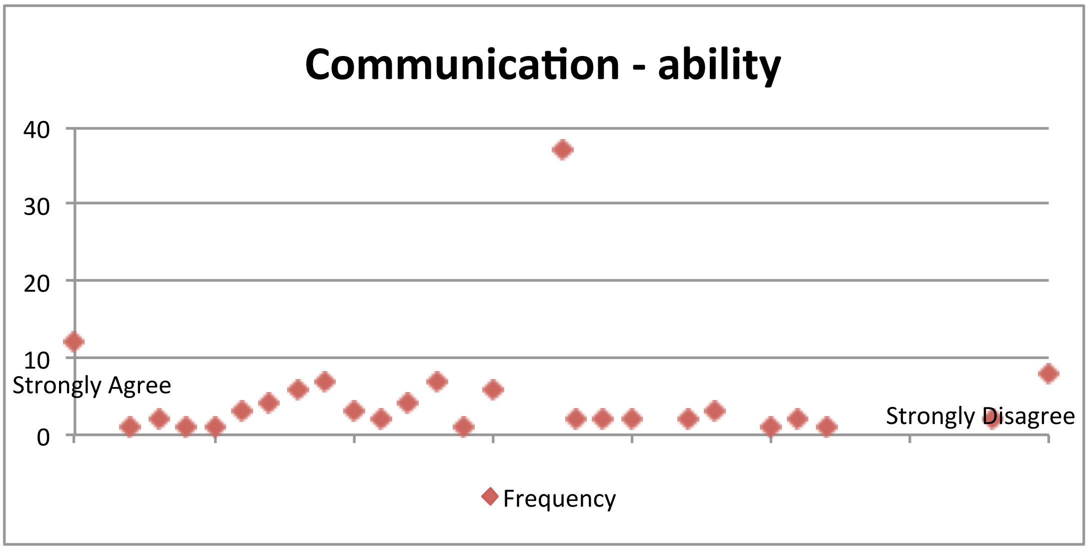
Figure 8.11 Motion: Responses around the TC System Self-Driven Learning

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, agreed that their ability to self-drive their learning had increased since the start of this unit, and most felt confident in their abilities to be a an effective self-driven learner.

8.2.5 Communication

Question D5 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice*", three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*? The responses to the three questions are graphed below.





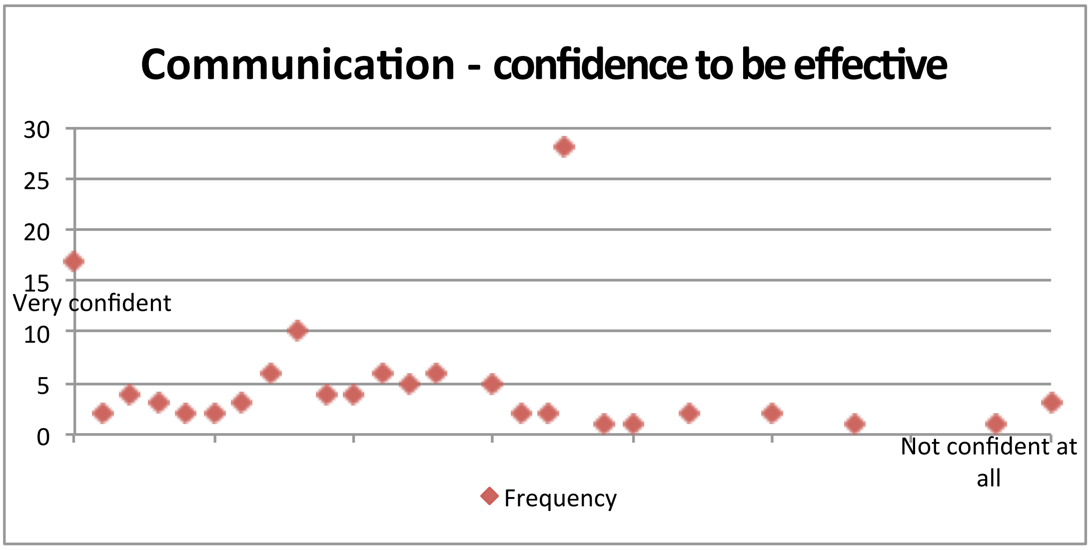
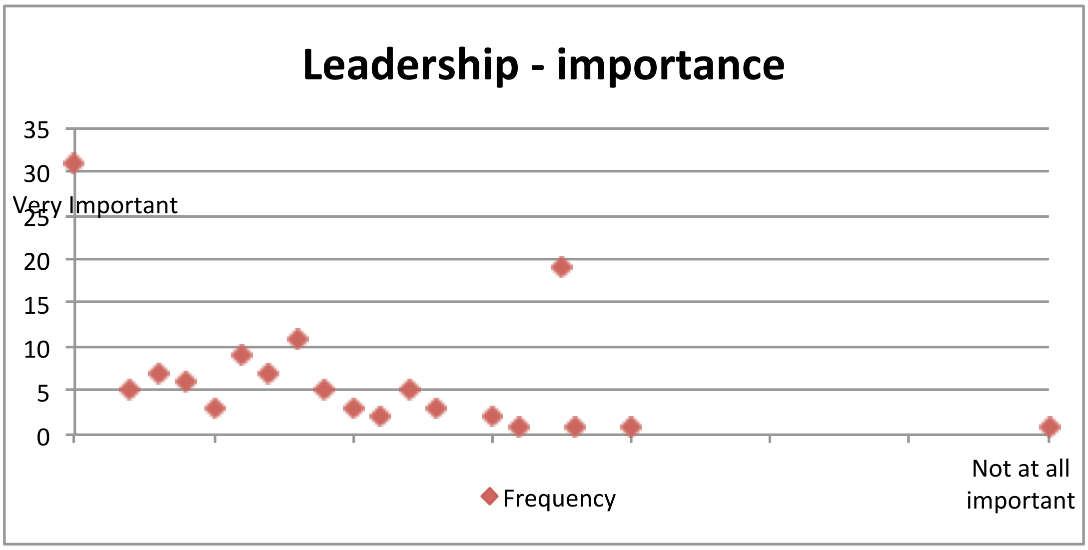


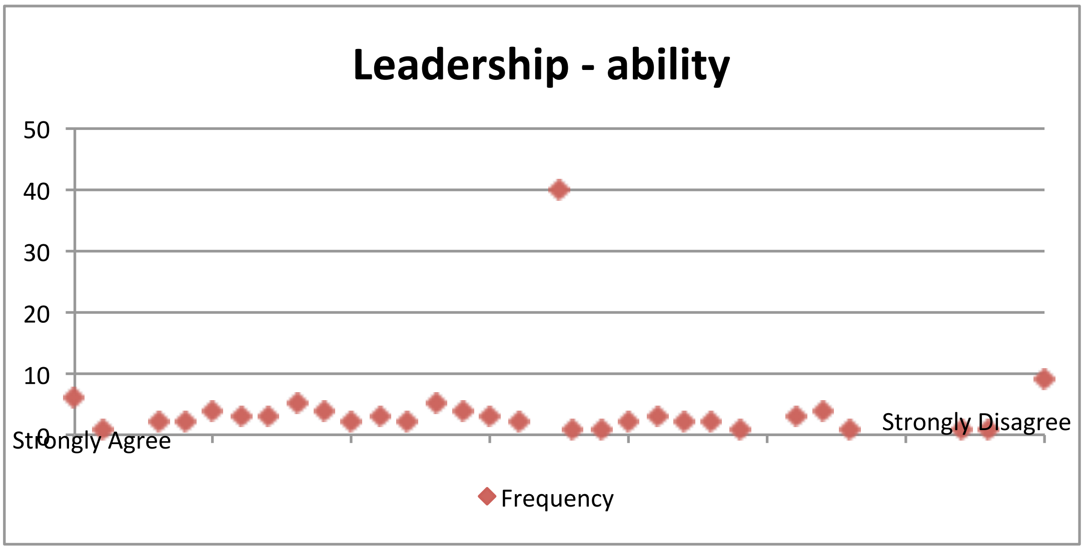
Figure 8.12 Motion: Responses around the TC Communication

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt confident in their abilities to be a an effective communicator.

8.2.6 Leadership

Question D6 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority"*, three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*? The responses to the three questions are graphed below.





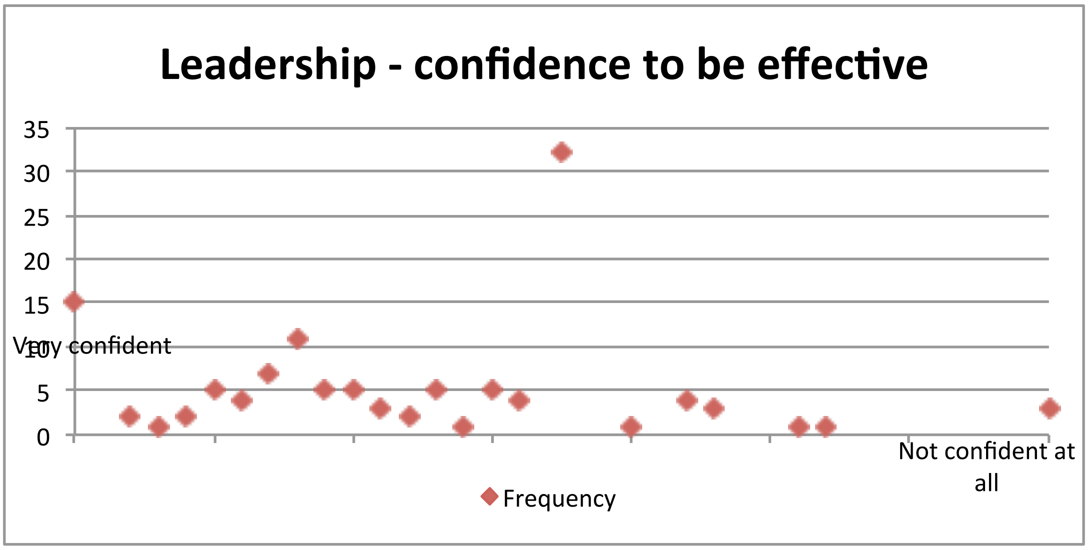
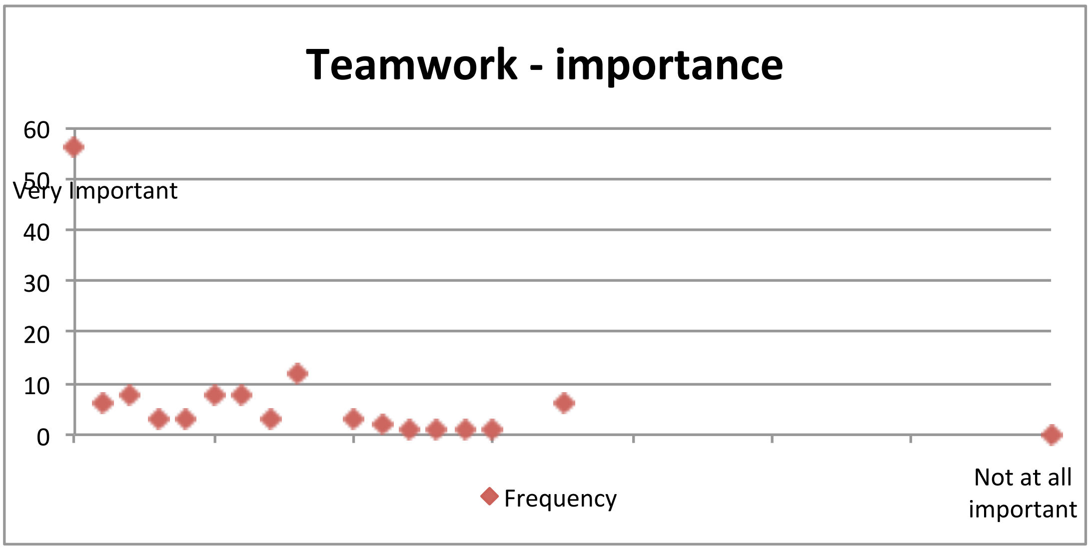


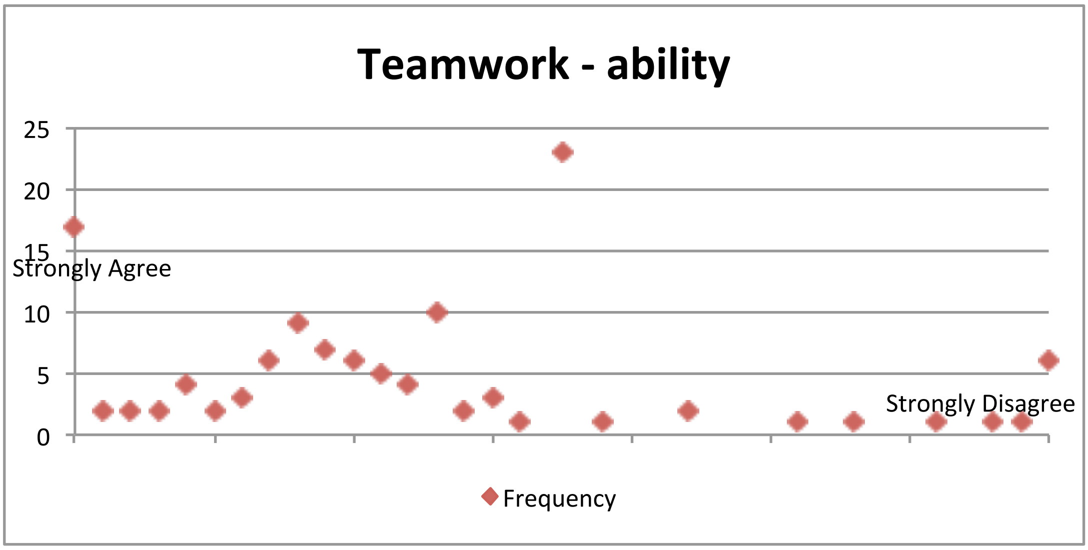
Figure 8.13 Motion: Responses around the TC Leadership

Students acknowledged the importance of the TC *Leadership* to successful engineering practice, neither agreed nor disagreed that their ability to lead had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective leader.

8.2.7 Teamwork

Question D7 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone"*, three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*? The responses to the three questions are graphed below.





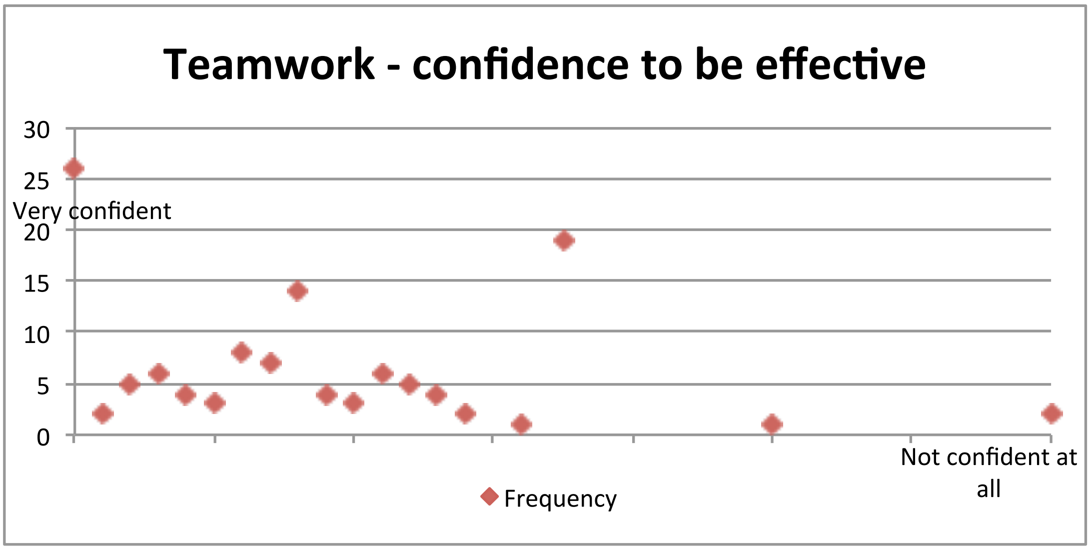


Figure 8.14 Motion: Responses around the TC Teamwork

All students acknowledged the importance of the TC *Teamwork* to successful engineering practice, more students agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and almost all students felt strongly confident in their abilities to be an effective team player.

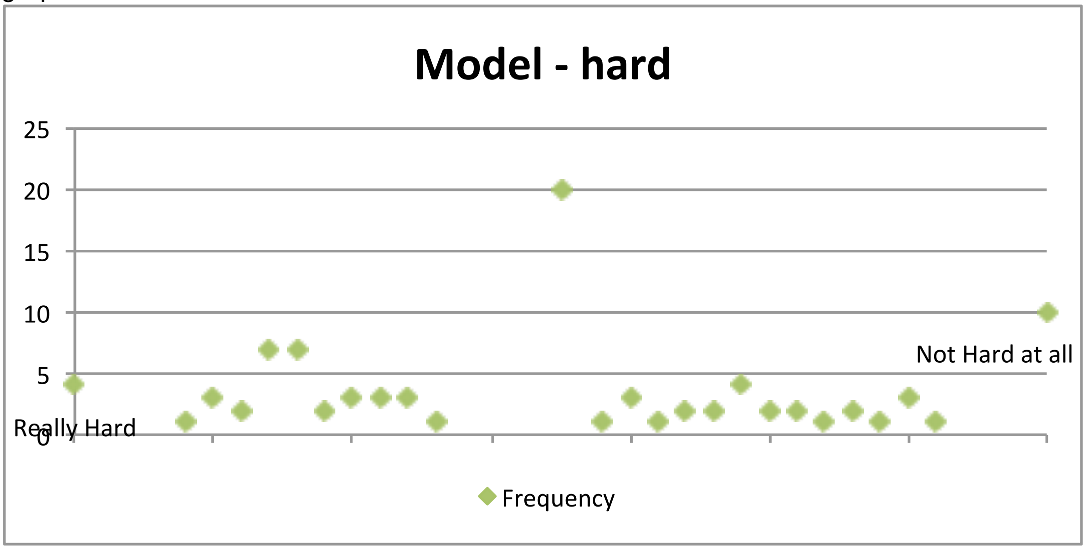
8.3 Energy

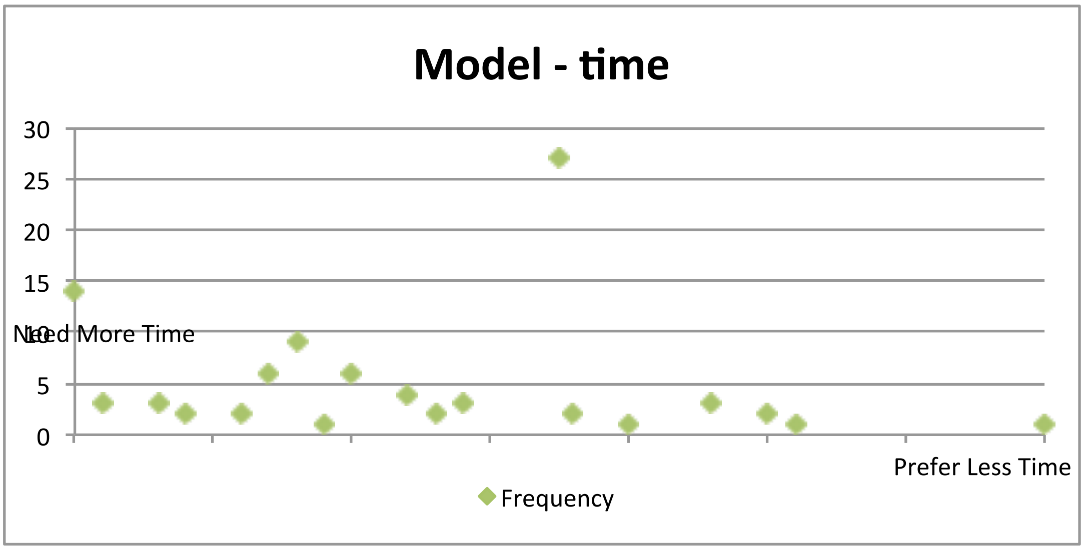
The questionnaire for Energy questioned student experiences around nine threshold concepts. Five threshold concepts (*Modelling, System Identification, Language, Phasors* and *Power*) were specific to the content in the unit, while the remaining four (*Self-Driven Learning, Communication, Leadership* and *Teamwork*) were common across all the engineering foundation units. A scatter diagram of the responses to each question is presented in the following sections.

8.1.1 Modelling

Question D1 asked about the TC System: In solving a circuit problem (identifying the voltages, currents, etc) the circuit can be simplified for analysis by choosing a appropriate circuit *model* (Thevenin, Norton), asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit?

This TC was part of all three units, Materials, Motion and Energy. The responses to the three questions are graphed below.





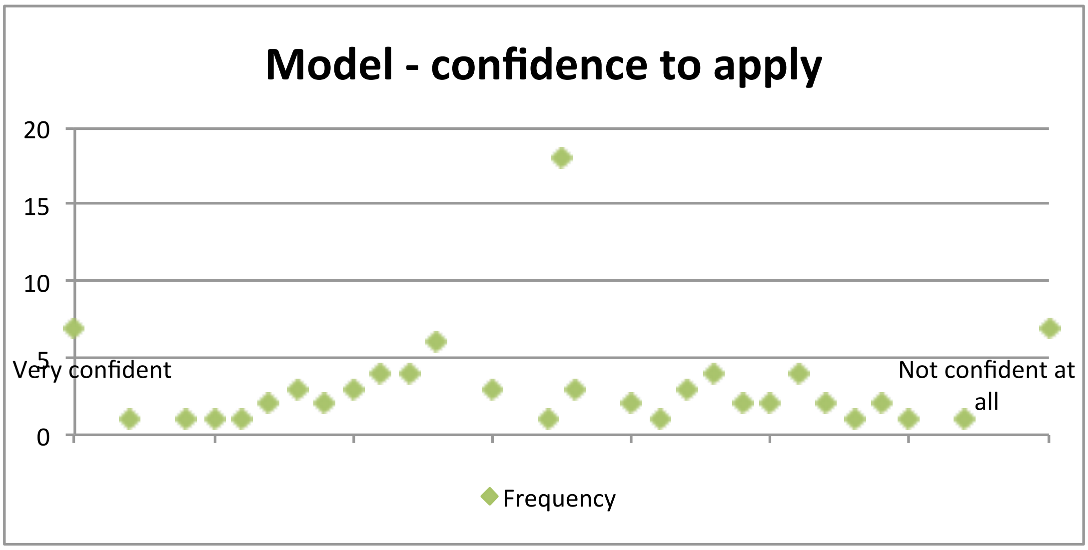
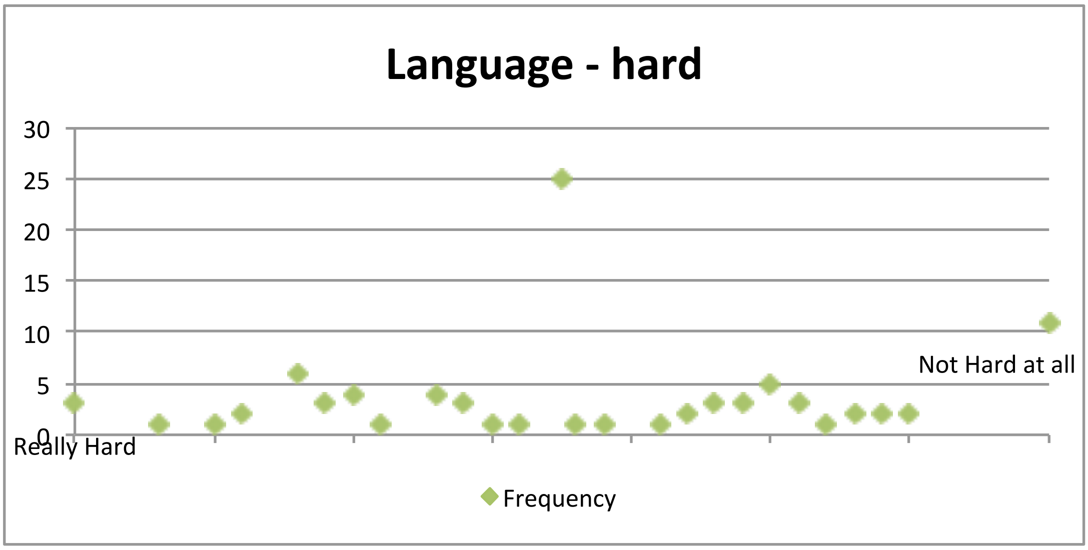


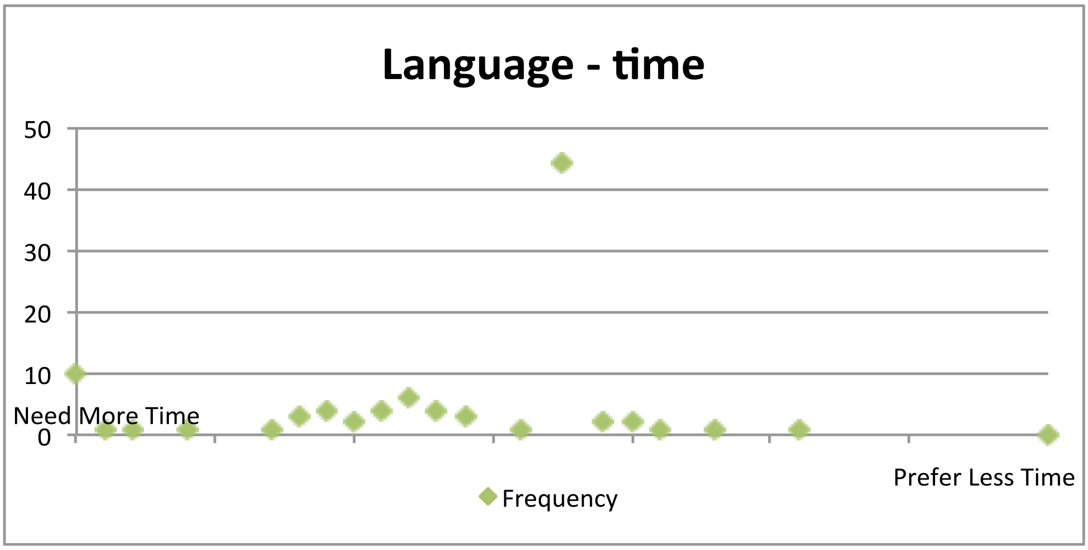
Figure 8.15 Energy: Responses around the TC Modelling

Students reported finding the TC *Modelling* neither hard nor easy, had a preference for more time, and in general felt confident applying this TC to the material covered so far in this unit.

8.1.2 Language

Question D2 asked about the TC *Language*: In solving a circuit problem (identifying the voltages, currents, etc), there is a *standard language* for *drawing* and *representing* the circuit - redrawing the circuit by rearranging the nodes and branches makes circuit analysis easier, asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





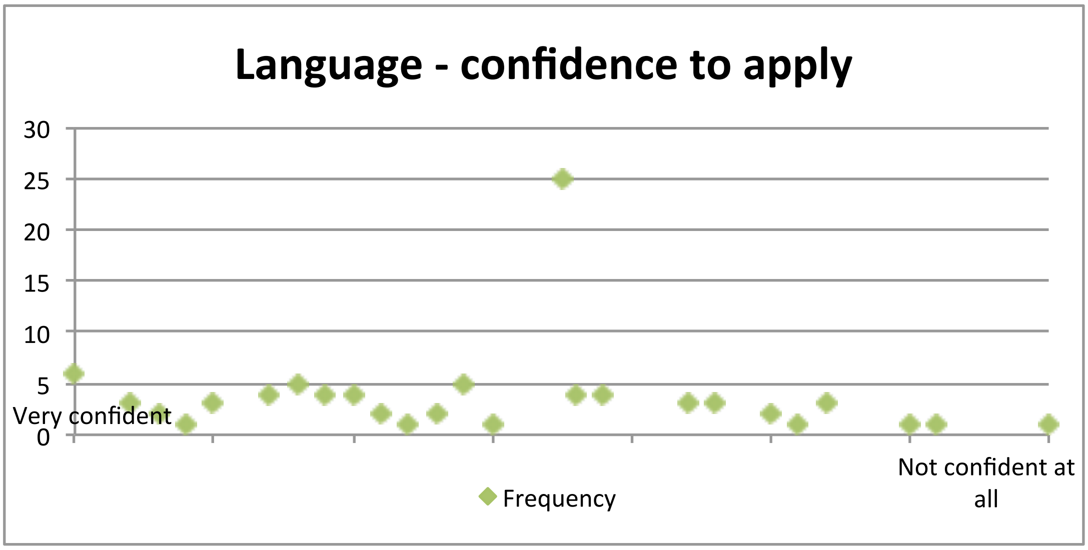
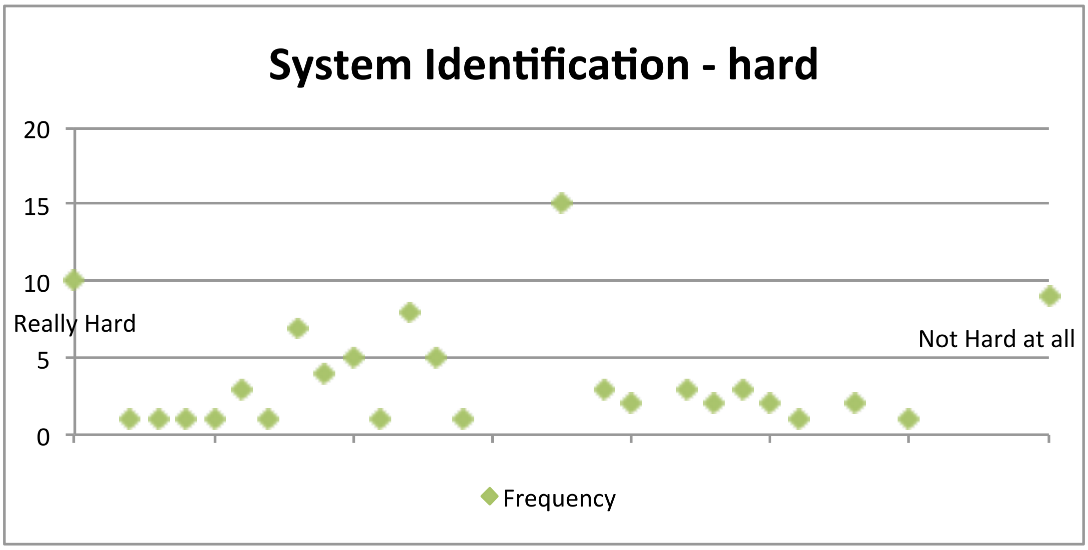


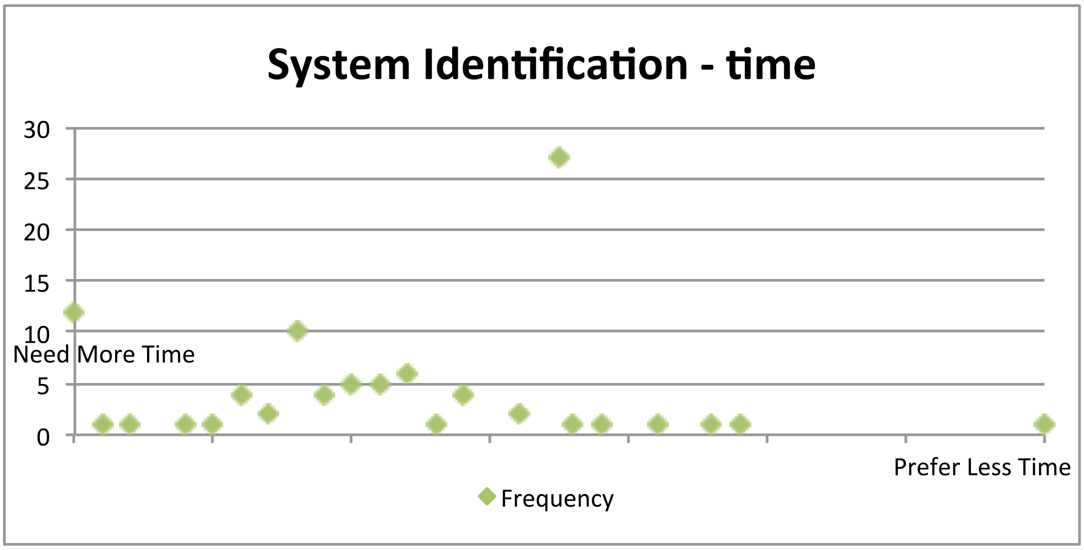
Figure 8.16 Energy: Responses around the TC Language

Students reported finding the TC *Language* neither hard nor easy, would have preferred more time, and felt confident in applying this TC to the material covered so far in this unit.

8.1.3 System Identification

Question D3 asked about the TC *System Identification*: Taking any circuit and drawing a dividing line across two points (identifying and defining the *system*), viewing / replacing one side of the circuit with its Thevenin/Norton equivalent and considering the other side as the "load", asking: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? This TC was also part of the Motion unit. The responses to the three questions are graphed below.





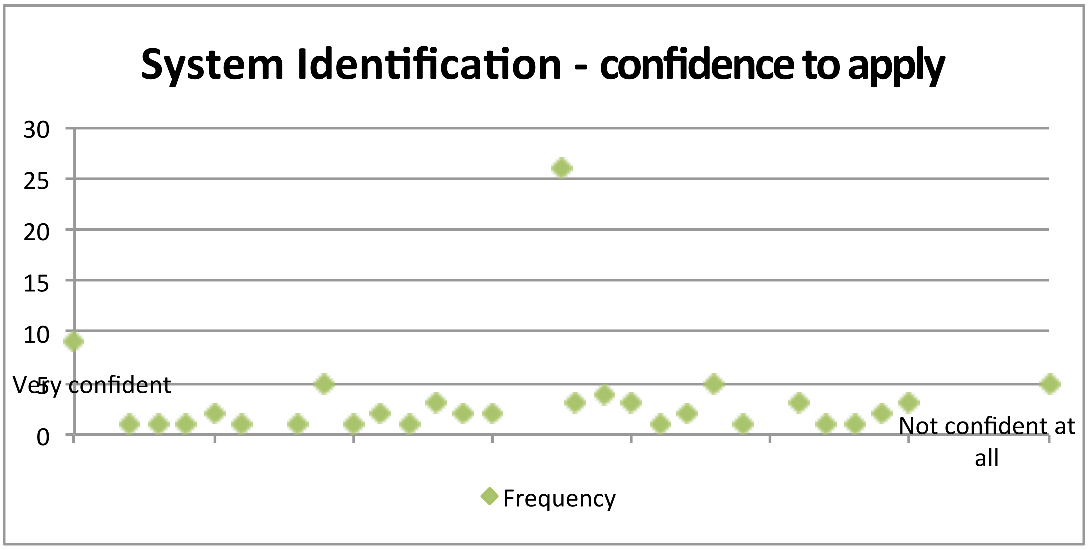
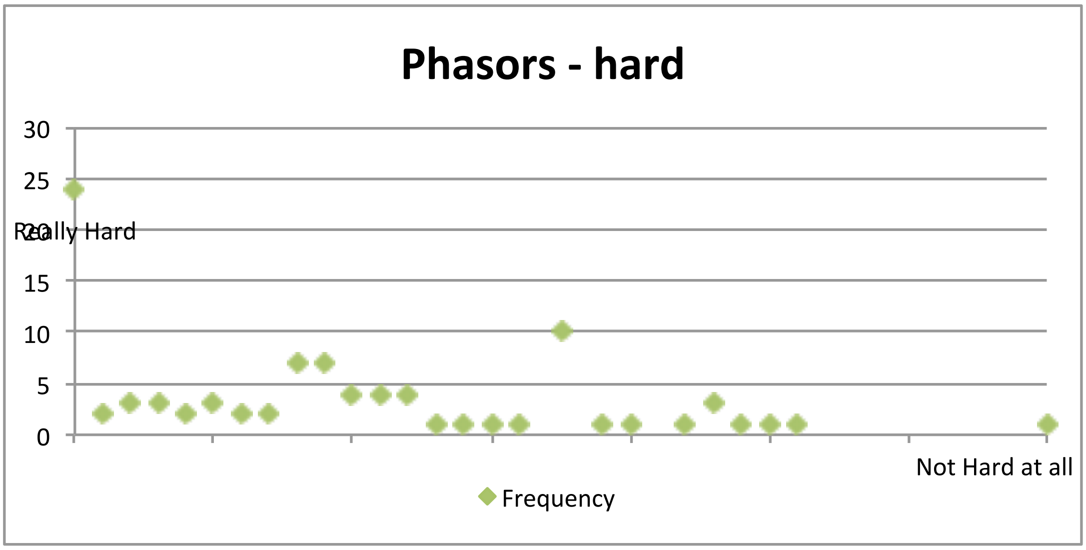


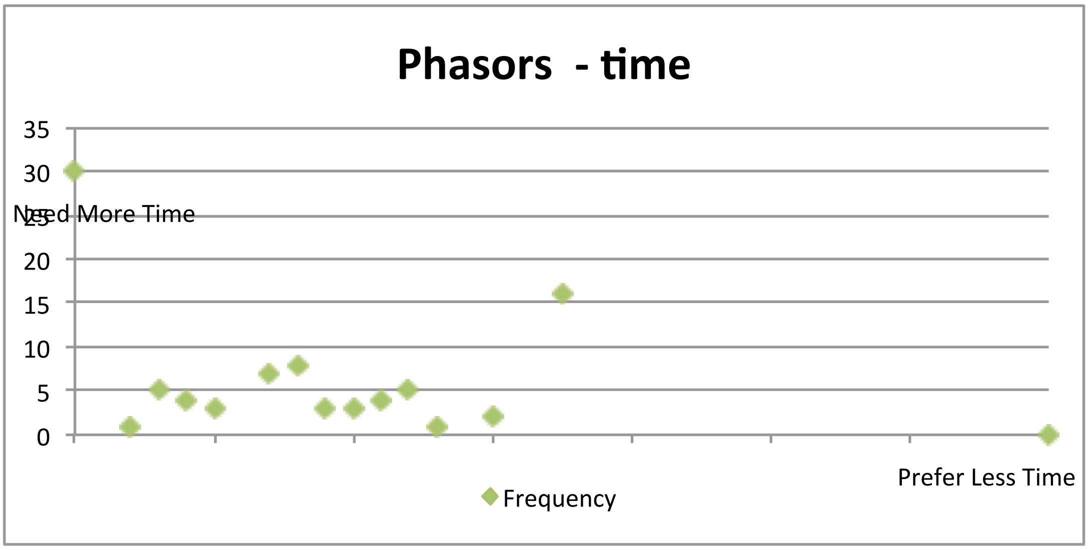
Figure 8.17 Energy: Responses around the TC System Identification

Students reported finding the TC *System Identification* harder than easier, would have preferred more time, and felt neither confident nor not confident applying this TC to the material covered so far in this unit.

8.1.4 Phasors

Question D4 asked about the TC *Phasors*: Phasors for analysis of AC circuits, and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





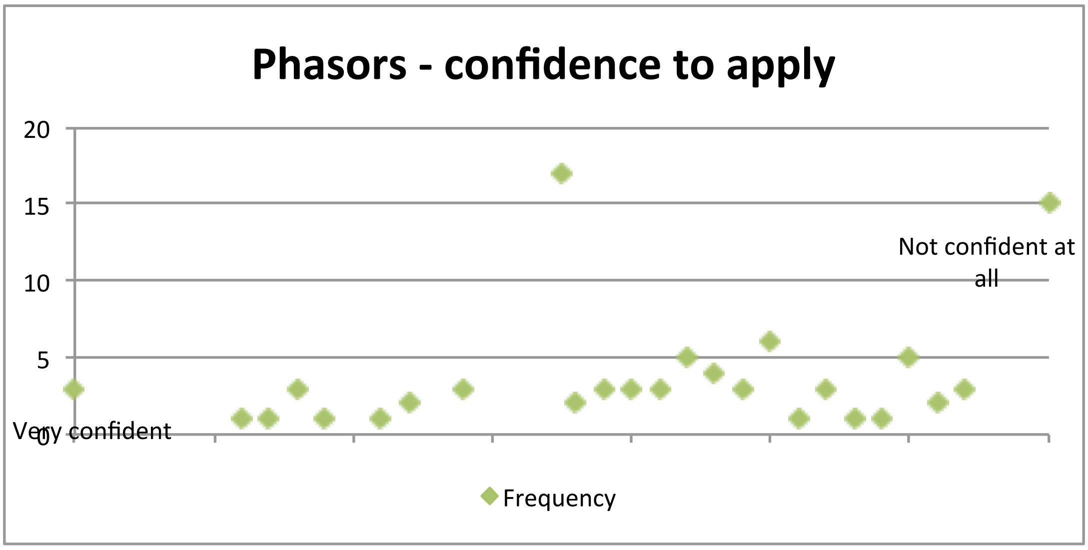
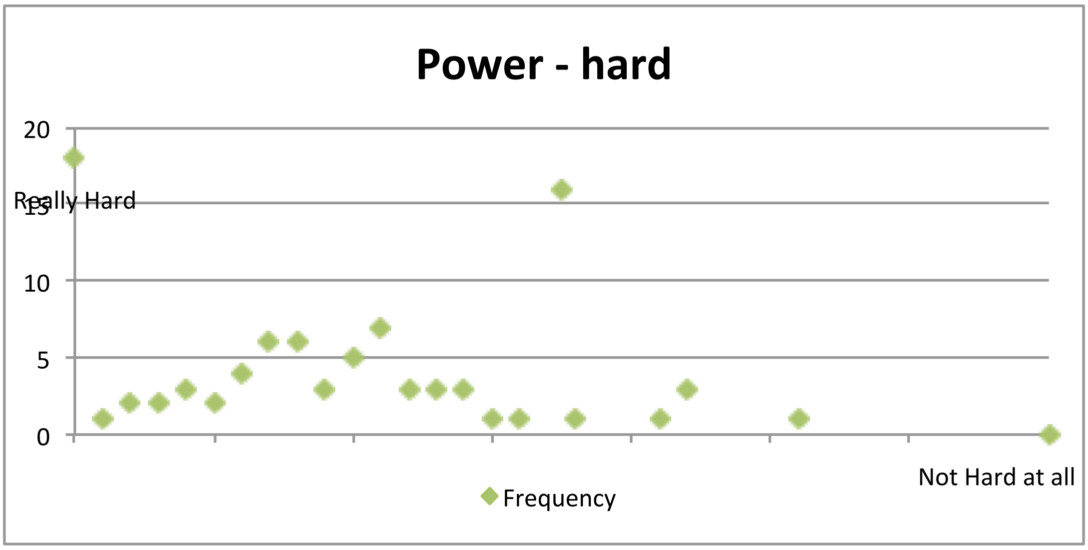


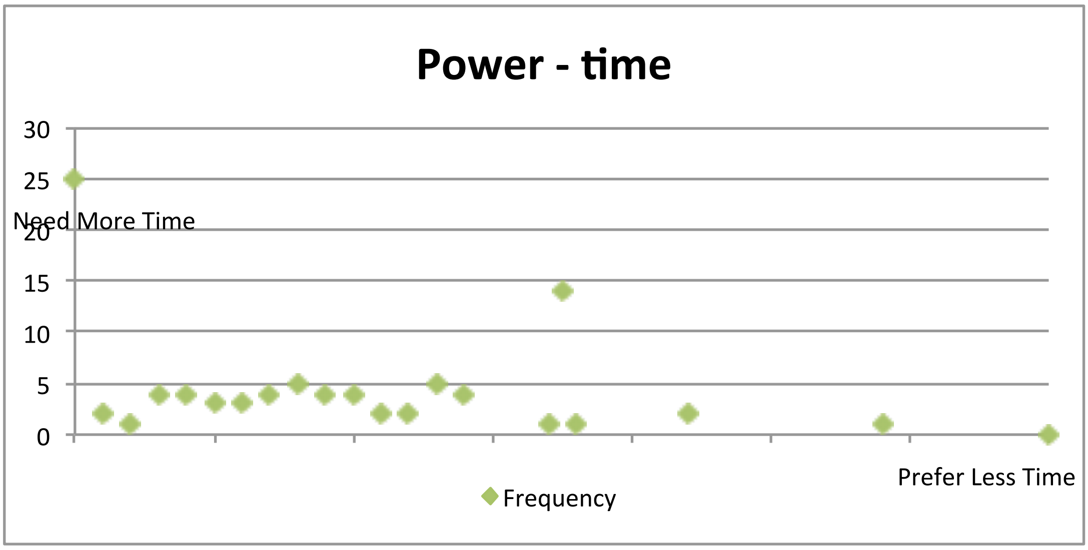
Figure 8.18 Energy: Responses around the TC Phasors

Students reported finding the TC *Phasors* hard, the hardest TC encountered so far. All students sought more time to engage with the TC *Phasors*. Most students did not feel confident applying this TC to the material covered so far in this unit.

8.1.5 Power

Question D5 asked about the TC *Power*: Reactive Power: vs Real Power and Complex Power, and asked: (i) How hard was this concept; (ii) Was enough time allocated in this unit to enable you to learn this concept; and (iii) How confident do you feel about applying this concept to the material covered so far in this unit? The responses to the three questions are graphed below.





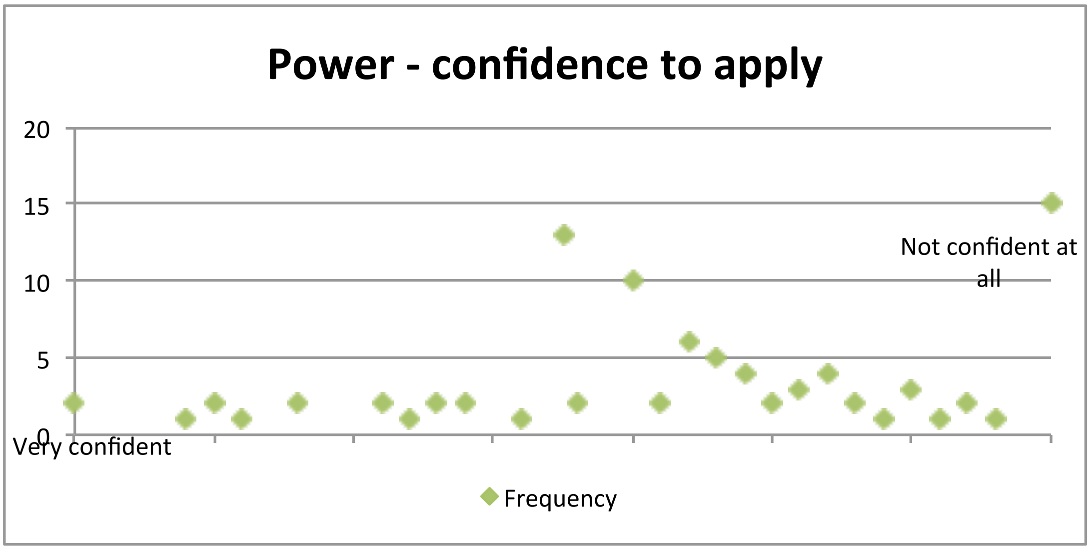
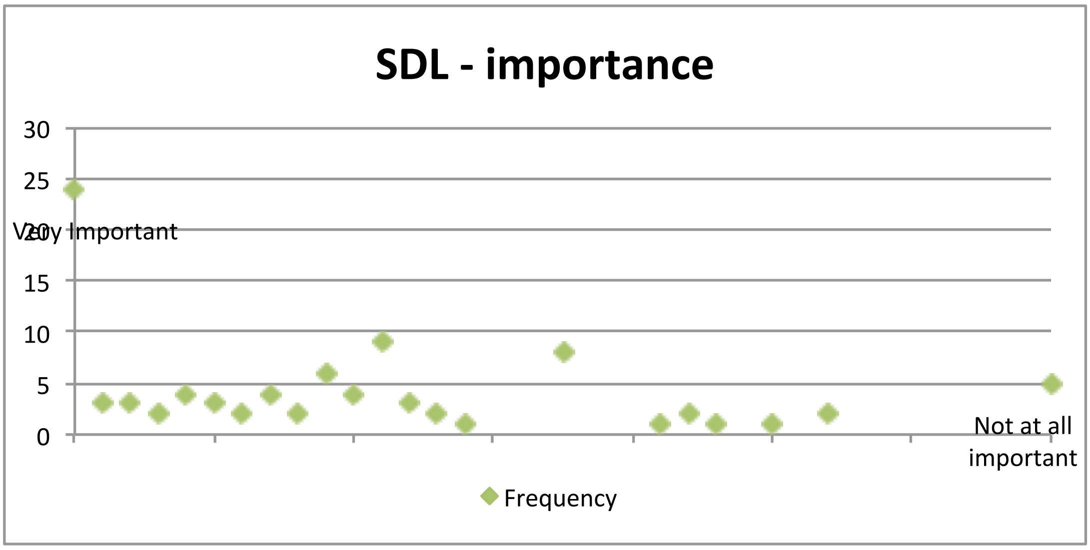


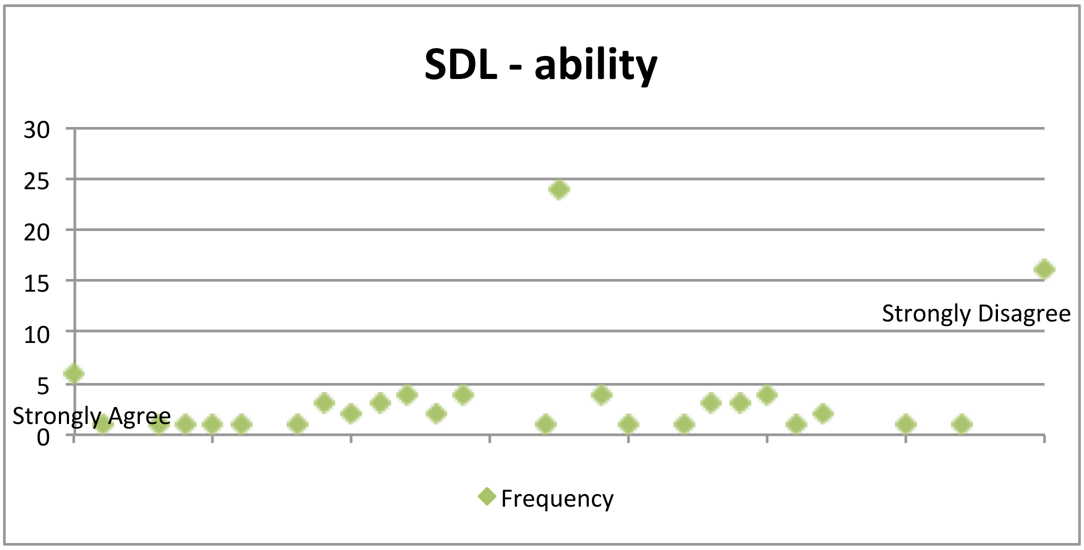
Figure 8.19 Energy: Responses around the TC Power

Students reported finding the TC *Power* hard, would have preferred more time, and in general did not feel confident applying this TC to the material covered so far in this unit.

8.1.6 Self Driven Learning

Question D6 asked about the first of the four threshold concepts / understandings common to the engineering foundation units, *Self-Driven Learning*. Described as "*there are different ways to learn and from different sources*", three questions were asked: (i) How **important** do you believe *self-driven learning* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to be a *self-drive learning;* and (iii) How confident do you feel about your abilities to be an **effective** *self-driven learner*? The responses to the three questions are graphed below.





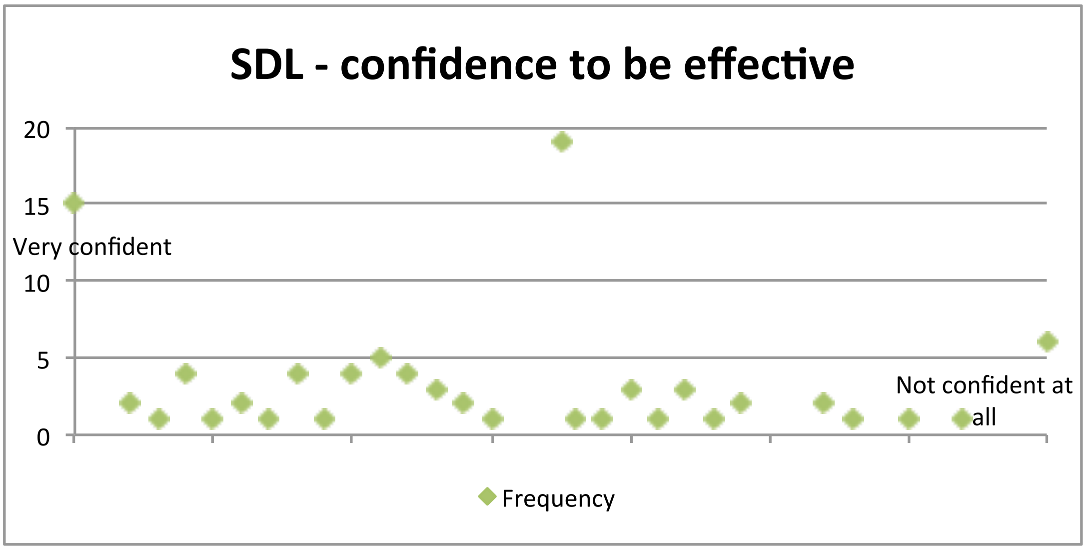
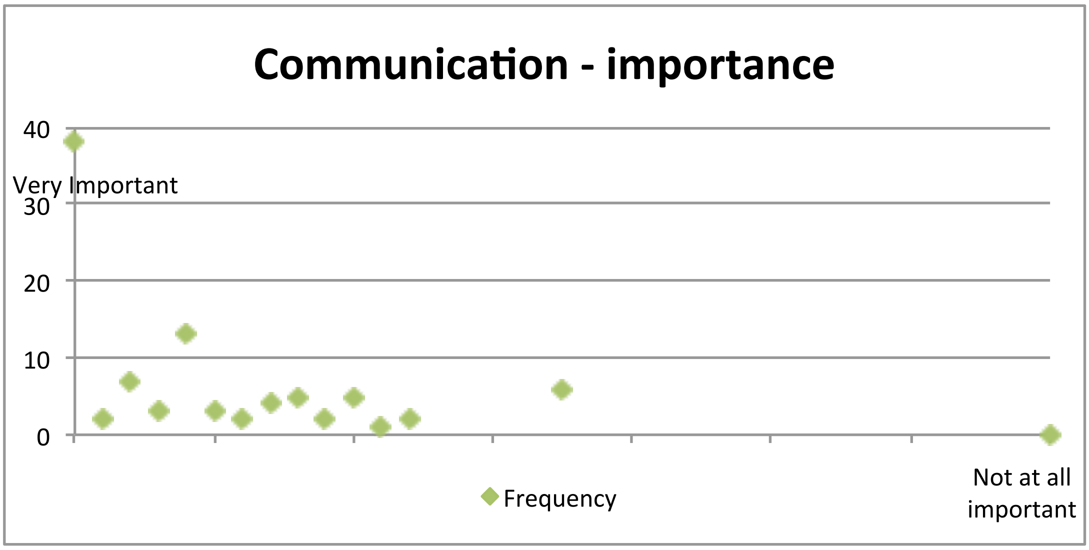


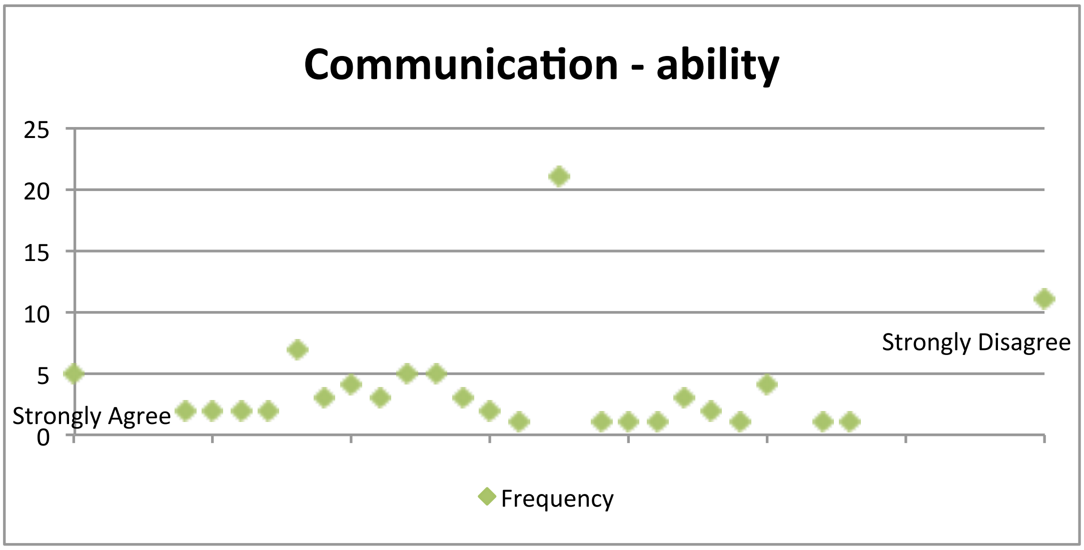
Figure 8.20 Energy: Responses around the TC Self-Driven Learning

Students acknowledged the importance of the TC *Self-Driven Learning* to successful engineering practice, neither agreed nor disagreed that their ability to self-drive their learning had increased since the start of this unit, and felt confident in their abilities to be an effective self-driven learner.

8.1.7 Communication

Question D7 asked about the second of the four threshold concepts / understandings common to the engineering foundation units, *Communication*. Described as "*two - way, effective communication in many forms is critical to engineering practice*", three questions were asked: (i) How **important** do you believe *communication* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *communicate;* and (iii) How confident do you feel about your abilities to be an **effective** *communicator*? The responses to the three questions are graphed below.





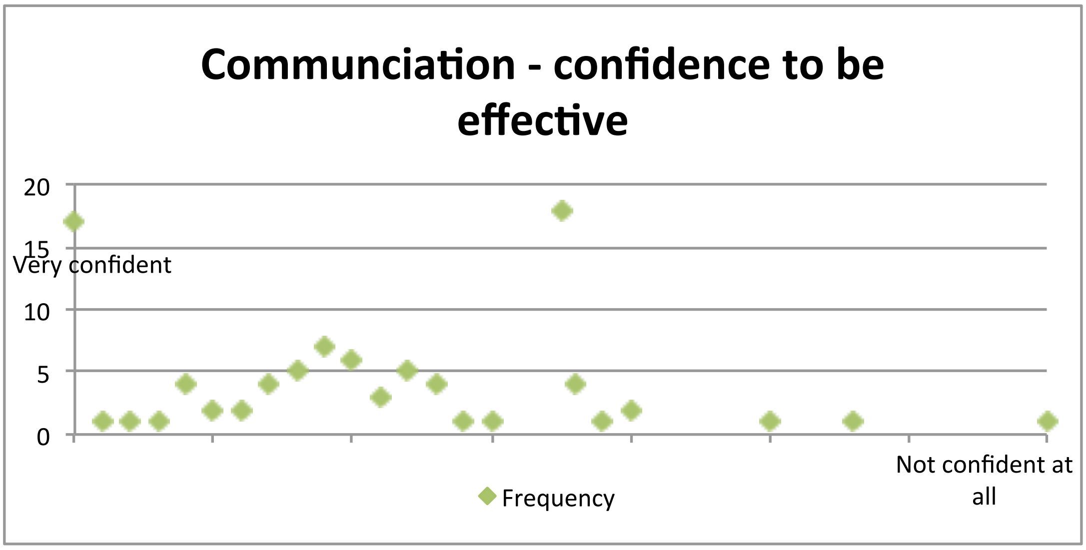
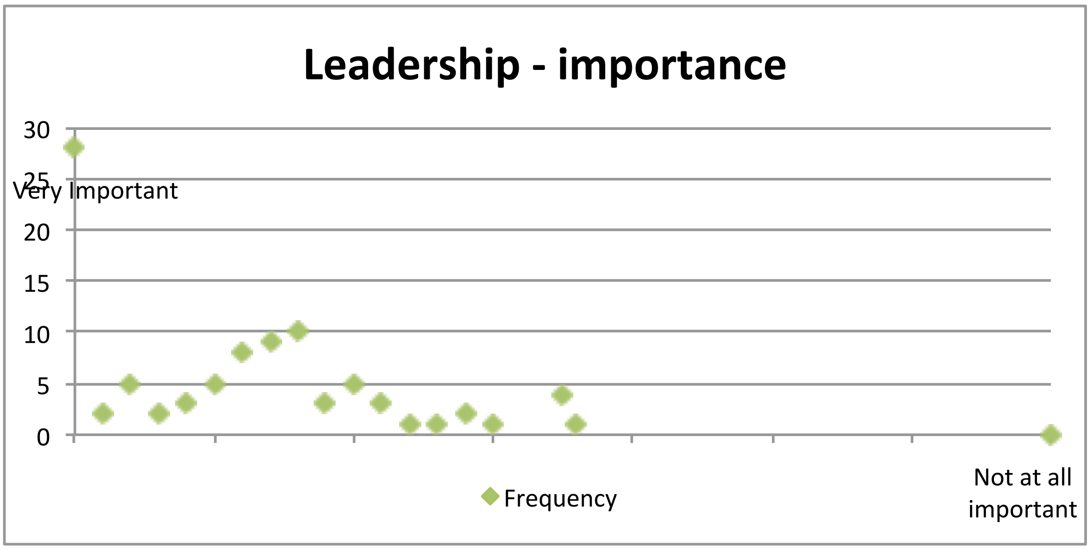


Figure 8.21 Energy: Responses around the TC Communication

Students acknowledged the importance of the TC *Communication* to successful engineering practice, agreed more than disagreed that their ability to communicate had increased since the start of this unit, and felt strongly confident in their abilities to be a an effective communicator.

8.1.8 Leadership

Question D8 asked about the third of the four threshold concepts / understandings common to the engineering foundation units - *Leadership*. Described as "*Engineers spend much of their time coordinating the work of people over whom they might have no direct authority*", three questions were asked: (i) How **important** do you believe *leadership* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a leader;* and (iii) How confident do you feel about your abilities to be an **effective** *leader*? The responses to the three questions are graphed below.



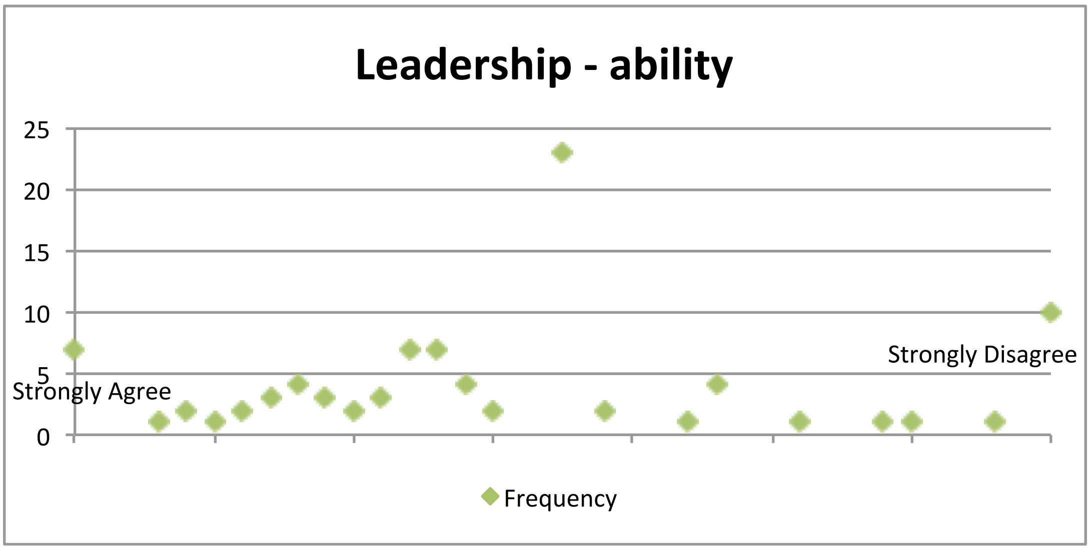
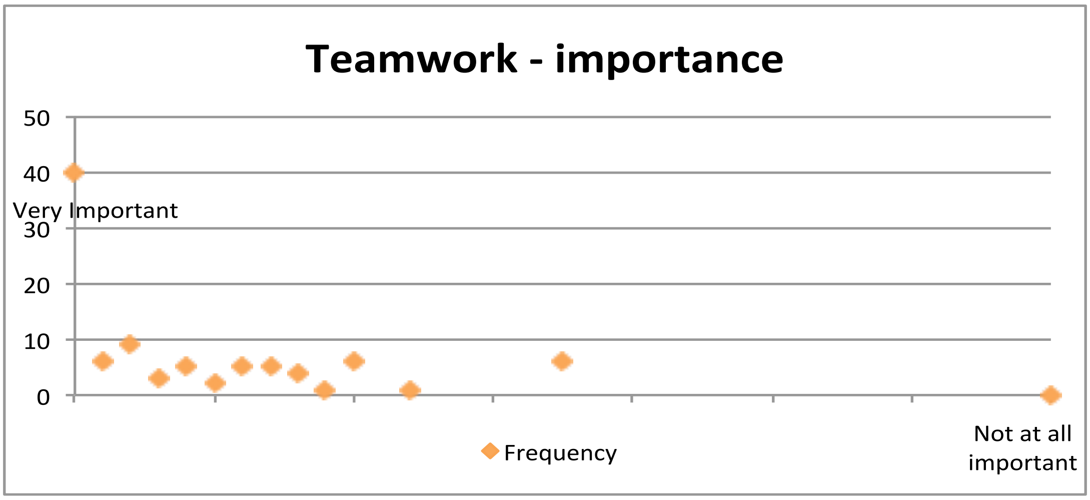


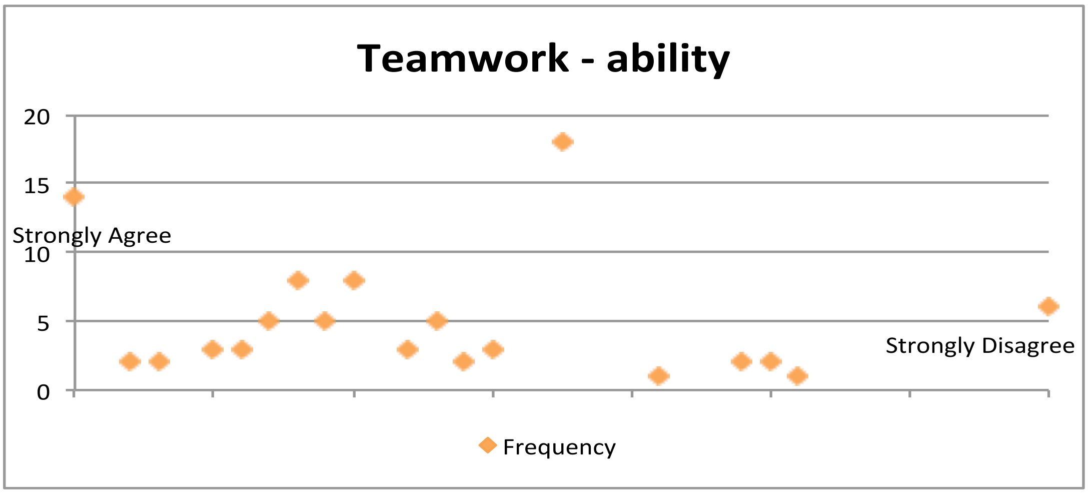
Figure 8.22 Energy: Responses around the TC Leadership

All students acknowledged the importance of the TC *Leadership* to successful engineering practice. Most students agreed more than disagreed that their ability to lead had increased since the start of this unit, and most students felt strongly confident in their abilities to be an effective leader.

8.1.9 Teamwork

Question D9 asked about the fourth of the four threshold concepts / understandings common to the engineering foundation units - *Teamwork*. Described as "*Engineers spend much of their time working with others; teams can achieve more than the sum of the individuals working alone"*, three questions were asked: (i) How **important** do you believe *teamwork* is to successful engineering practice?; (ii) Since the start of this unit, I have gained a greater **ability** to *be a team player;* and (iii) How confident do you feel about your abilities to be an **effective** *team player*? The responses to the three questions are graphed below.





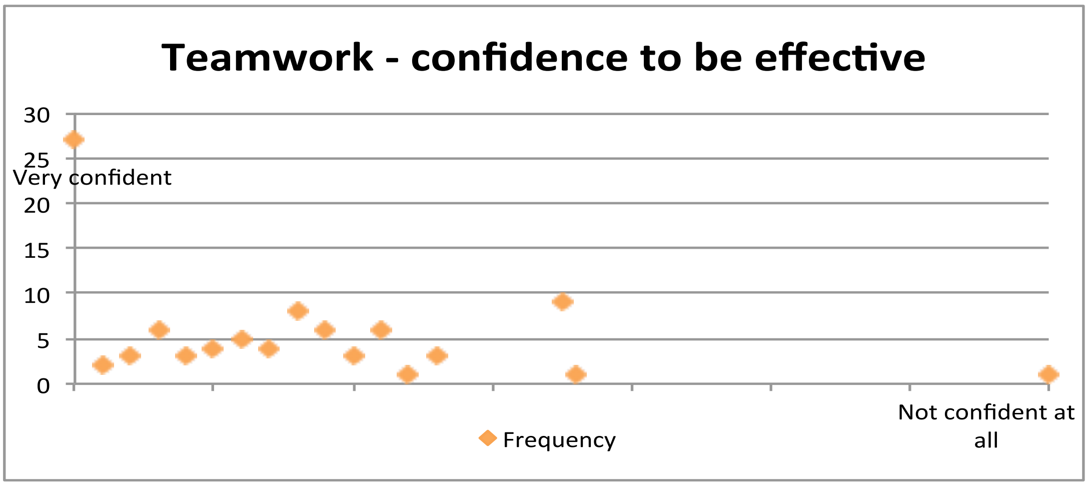


Figure 8.23 Energy: Responses around the TC Teamwork

All students acknowledged the importance of the TC *Teamwork* to successful engineering practice. Most students agreed more than disagreed that their ability to be a team player had increased since the start of this unit, and all students felt confident in their abilities to be an effective team player.

Appendix 9 Responses to Survey Part E: Final Comments

Materials

Comments are sorted in alphabetical order. Comments in brackets () were comments that had been written by the students elsewhere on the questionnaire. Comments in [] are researcher notes.

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